# IMPROVING THE LABORATORY EXPERIENCE FOR AMERICA'S HIGH SCHOOL STUDENTS

## HEARING

BEFORE THE

SUBCOMMITTEE ON RESEARCH AND SCIENCE EDUCATION

COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED TENTH CONGRESS

FIRST SESSION

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**March 8, 2007**

# IMPROVING THE LABORATORY EXPERIENCE FOR AMERICA'S HIGH SCHOOL STUDENTS

**THURSDAY, MARCH 8, 2007**

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON RESEARCH AND SCIENCE EDUCATION,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
*Washington, DC.*

The Subcommittee met, pursuant to call, at 3:10 p.m., in Room 2320 of the Rayburn House Office Building, Hon. Brian Baird [Chairman of the Subcommittee] presiding.

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The Subcommittee on Research and Science Education

Hearing on:

*"Improving the Laboratory Experience for America's High School Students"*

2318 Rayburn House Office Building
Washington, D.C.

Thursday, March 8, 2007
2:00 PM – 4:00 PM

WITNESS LIST

Panel 1

**Congressman Rubén Hinojosa**
*U.S. Representative*
*Texas, 15th District*

Panel 2

**Dr. Arthur Eisenkraft**
*Distinguished Professor of Science Education*
*University of Massachusetts, Boston*

**Ms. Linda Froshauer**
*President*
*National Science Teachers Association*

**Dr. Jerry Mundell**
*Professor of Chemistry*
*Cleveland State University*

HEARING CHARTER

## SUBCOMMITTEE ON RESEARCH AND SCIENCE EDUCATION
## COMMITTEE ON SCIENCE AND TECHNOLOGY
## U.S. HOUSE OF REPRESENTATIVES

# Improving the Laboratory Experience for America's High School Students

THURSDAY, MARCH 8, 2007
2:00 P.M.–4:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

**Purpose**

On March 8, 2007 the Committee on Science and Technology will hold a hearing to receive testimony on the shortcomings of the use of laboratories in high school science education and to consider related legislation. H.R. 524 directs the National Science Foundation (NSF) to establish a pilot program of grants to partnerships of high schools and other institutions to identify best practices for improving the educational effectiveness of science laboratories. The bill is in response to the findings of the National Research Council's (NRC) 2005 report, *America's Lab Report: Investigations in High School Science.*

This hearing will discuss how issues like lack of coordination between the laboratory exercises and classroom lectures, inadequately trained teachers, languishing facilities, and current high school organization diminish the value these exercises can have or prohibit them all together. Most importantly, this hearing will highlight how a strong hands-on experience can create scientifically literate students, interested in pursuing a career in science.

**Witnesses**

*Panel 1*

**The Honorable Rubén Hinojosa,** the Representative from the 15th district of Texas

*Panel 2*

**Dr. Arthur Eisenkraft,** Distinguished Professor of Science Education, Director of the Center of Science and Math in Context, University of Massachusetts, Boston, Graduate College of Education; co-author of *America's Lab Report: Investigations in High School Science.*

**Mrs. Linda Froschauer,** President, National Science Teachers Association.

**Dr. Jerry Mundell,** Adjunct Professor and General Chemistry Laboratory Manager, Department of Chemistry, Cleveland State University, Cleveland, Ohio.

**Overarching Questions**

- How important is the laboratory experience in teaching students to understand scientific concepts?
- What are the common obstacles for creating and maintaining laboratories and developing curriculum to teach laboratory experiences?
- Will H.R. 524 help address those obstacles and make lab instruction more accessible to all students?

**Summary of National Research Council's America's Lab Report: Investigations in High School Science**

In 2005 the National Research Council published *America's Lab Report: Investigations in High School Science,* a study which looked at the role laboratory learning can have for the country's high school students, the current situation of laboratory learning, and what can be done to improve these often unproductive programs. The NSF commissioned this study as a precursor to fulfilling the mandate Congress gave

the agency in the 2002 *NSF Authorization Act* (P.L. 107–368) to launch a secondary school systemic initiative, which would "promote scientific literacy" and "meet the mathematics and science needs for students at risk of not achieving State student academic achievement standards." Specifically, section 8(E) of the law required NSF to support programs for such activities as "laboratory improvement and provision of instrumentation as part of a comprehensive program to enhance the quality of mathematics, science, engineering, and technology instruction." As scientific and technical fields become an increasing part of the global economy, it is imperative that America's students be adequately prepared to compete for high-tech jobs and create the innovation that drives the economy.

The NRC report found that the laboratory science programs in high school classrooms are in disarray, and certain factors seriously hamper efforts to improve them. The NRC report committee concluded that there exists no commonly agreed upon definition of laboratories in high schools amongst researchers and educators. Without agreement on a definition of what constitutes a laboratory exercise, research and the accumulation of knowledge on specific methods to improve the experience for student is undirected, difficult to classify, and difficult to draw conclusions from.

Though research on laboratory exercises may not be well delineated, American students poor achievement in science is. Assessments of national trends in science learning show that American students at all levels are at roughly the same level of proficiency in science that they were at 30 years ago. International assessments show American students fare worse than their peers in other countries. It is clear from studies of undergraduate science students that many are unprepared for college-level work. A 2002 survey of first-year students planning a major in science, technology, engineering, or mathematics (STEM) showed 20 percent in need of remedial math work and 10 percent in need of remedial science work. Those who come unprepared for college-level work often do not succeed and will leave the STEM fields.

Through their review of the available studies, the NRC report committee developed a list of desired outcomes for laboratory experiences. The studies showed that laboratory experiences may help students enhance mastery of subject matter, develop practical skills with tools and instrumentation, develop teamwork abilities, and cultivate an interest in science. Additionally, the NRC committee noted that laboratory experiences expose students to the complexity and ambiguity of real empirical work. These concepts cannot be taught in lectures or textbooks. Students must interact directly with scientific phenomena to appreciate this aspect of science.

Unfortunately, the typical laboratory experience for most of the country's high school students is poor. Studying the current situation in the classroom, the NRC report committee concluded that teachers often implement laboratory exercises that are not synchronized to the classroom lecture, do not have clear learning goals, neglect student feedback and discussion, or are not designed to integrate the learning of science material with the learning of scientific process. Teachers are rarely provided adequate pre-service training or in-service professional development to lead these exercises. The lack of flexibility in high school organization can also impedes the implementation of more effective laboratory exercises.

The NRC report committee came to the conclusion that State standards are also to blame for the failures in the laboratory. Teachers must cover an extensive list of standards, leaving little time for the development and implementation of laboratory curricula. The NRC report points to one study of California State standards showing that students are required to carry out laboratory exercises that engage in activities like hypothesis forming, data collection, problem solving, but at the same time they must also master an extensive list of science topics that puts impossible time constraints on laboratory exercises. And, since large-scale assessments of science mastery are not designed to measure student attainment of laboratory goals, laboratory exercises are further neglected.

**H.R. 524**

H.R. 524 amends the *NSF Authorization Act of 2002* to establish a pilot program at NSF to fund grants to improve laboratory sciences. The grants, which require a funding match, must go to partnerships between high schools and institutions of higher learning (including community colleges), businesses, eligible non-profit organizations, State educational, or other public agencies, National labs, or community-based organizations. These grants are intended to support the development of laboratory exercises integrated with classroom curriculum and teacher development, and to provide for the acquisition of laboratory equipment and instrumentation. A provision is also made in the bill for supporting these activities in schools serving minority populations under-represented in science and engineering.

The pilot projects authorized by H.R. 524 will address some of the needs for research and demonstration activities raised by the NRC report. Because the NRC committee found the evidence on best practices for high school science laboratories too inconclusive to make specific recommendations, they delivered a series of questions in five broad categories for policy-makers, researchers, and educators to address. These areas are: the assessment of student learning in laboratory exercises; the most effective pedagogy methods for laboratory exercises; how to serve a diverse population of learners; the best organization of schools and school systems for a well-functioning laboratory program; and the best way to prepare educators to administer effective laboratory programs.

**Questions for Witnesses**

The panelists were asked to address the following questions in their testimony before the Subcommittee:

*Dr. Arthur Eisenkraft*

- Please explain the background that was the impetus of the National Research Council's report *America's Lab Report: Investigations in High School Science.* What were the report's findings? Can you characterize one or two as being the most critical in implementing a successful laboratory program?
- What recommendations would the study committee make to improve the laboratory experience for students?

*Mrs. Linda Froschauer*

- How important is the laboratory experience for students in understanding scientific concepts? What is current state of laboratory facilities and instruction in the country?
- What are the biggest concerns your member science teachers have about laboratory education and implementing an effective program?
- Will H.R. 524 assist in developing and implementing effective science laboratory programs for high school students?

*Dr. Jerry Mundell*

- Please describe the curriculum you've developed for students in the Cleveland Public schools. How has your position at Cleveland State University informed your motivation and ideas for high school laboratory curriculum?
- What obstacles have you encountered in creating lab programs for high school students? Have you assessed students' mastery of concepts using the curriculum you've developed? What methods have you used to measure this?
- Will H.R. 524 assist in developing and implementing effective science laboratory programs for high school students?

**H.R. 524, To Establish a Laboratory Science Pilot Program at the National Science Foundation**

*Summary of Major Provisions of the Bill*

This bill would establish a pilot program at the National Science Foundation to award grants to partnerships to improve science laboratories at the secondary school level. The grants may be used for a variety of activities to improve the laboratory experience for high school students with particular regard to minorities who are under-represented in science and engineering.

*Section-by-Section Analysis of H.R. 524*

*Section 1. Findings*

*Section 2. Grant Program*

– Amends Section 8(8) of the *National Science Foundation Authorization Act of 2002* to include a section authorizing a laboratory science pilot program for secondary schools.

– Requires the National Science Foundation Director to establish a pilot program designated as 'Partnerships for Access to Laboratory Science' to award grants to partnerships to improve laboratories and provide instrumentation as part of a comprehensive program to enhance the quality of mathematics, science, engineering, and technology instruction at the secondary school level.

– Requires that the grants awarded be used for the following types of activities: to purchase, rent, or lease equipment; maintain, renovate, or improve laboratory facilities; engage in professional development and training activities for teachers; develop instructional programs designed to integrate the laboratory experience with classroom instruction and be consistent with State mathematics and science academic achievement standards; the training in laboratory safety for school personnel; the design and implementation of hands-on laboratory experience to encourage the interest of individuals identified in section 33 or 34 of the *Science and Engineering Equal Opportunities Act* (42 U.S.C. 1885a or 1885b) in mathematics, science, engineering, and technology and help prepare such individuals to pursue post-secondary studies in these fields; and assessment of the activities funded by this pilot program.

– Requires the grants awarded under amended subparagraph A be to a partnership that includes an institution of higher education or a community college, a high-need local educational agency, a business or eligible nonprofit organization, and may include a State educational agency, or other public agency, National Laboratory, or community-based organization.

– Requires that the federal cost share for these grants be no more than 50 percent.

*Section 3. Report*

– Requires the Director of the National Science Foundation to evaluate the effectiveness of activities carried out under this grant program and submit a report, no later than five years after the enactment of the act, to the Committee on Science and Technology of the House of Representatives, and the Committees on Commerce, Science, and Transportation and on Health, Education, Labor, and Pensions of the Senate. The report shall identify best practices and materials developed and demonstrated by grant awardees.

*Section 4. Authorization of Appropriations*

– Authorizes the appropriation of $5,000,000 to the National Science Foundation for fiscal year 2008 and such sums that may be necessary for the three succeeding fiscal years to carry out this Act.

Chairman BAIRD. This hearing will come to order. I appreciate the presence of our witnesses, we had recent votes, so I apologize for the delay, but we are very glad you are all here.

We are also waiting on a fellow Member who undoubtedly is tied up with some other committee business. Mr. Hinojosa, we hope, will be here shortly. If he arrives, we will insert him into the proceedings as well.

I want to first welcome everyone, and thank you all for coming to this afternoon's hearing on *Improving the Laboratory Experience for America's High School Students.* This is particularly exciting for me. It marks the very first hearing of the Research and Science Education Subcommittee for this Congress, and I want to take just a moment to express how pleased I am to be able to chair this particular subcommittee.

I want to especially thank my good friend and colleague, Ranking Member Dr. Ehlers, who was the leader of this very committee until recently. He has been a true leader on the Science Committee in general, has extensive knowledge of and experience with the important issues that come before this committee, and I look forward to drawing upon his knowledge and his friendship, and also, working together in a bipartisan manner throughout this Congress. I am pleased he will be leading this subcommittee on the Republican side, and also, am glad to see Mr. Hall here.

Oh, Mr. Hinojosa is here. Well, welcome. We are just getting started. So come on up, my friend, and we will start with you once I get through all my initial palaver.

I also want to acknowledge, though she is not with us today, on the Democratic side, Eddie Bernice Johnson, who preceded me as the Democratic lead on this subcommittee, in her role as Ranking Member. I intend to continue her good work, and especially, her commitment to math and science education, particularly as it pertains to under-represented communities. I am pleased that Ms. Johnson has decided to continue her service on this committee.

As it is the first Committee hearing, I want to take just a brief moment to offer a few observations of how I will approach this committee, and hopefully, that will set the stage for some of what we will do in the future. I would say at the start that long before I was in Congress, I was a scientist. I hold a doctorate in clinical psychology, specialized in neuropsychology, and science is not just a committee I serve on, as I know it is the same with Dr. Ehlers. This is something that is in our blood. We are scientists. We are passionate about it, and I am passionate about it not just as a scientist, but as a Member of Congress. I believe that reason, informed by fact, is a pretty darn good way to lead your life, and it is a very good way to make public policy. And we are not alone in that. Those who know the history of this great country know that some of our greatest Founders, Franklin especially, but also Jefferson and Washington, as well, had a passionate commitment to science and to investigative research as a way to guide agriculture, as well as public policy.

At the same time, because I have been in the scientific field, I recognize that science has its share of problems, and there is room for improvement. And I want to underscore from the outset that ultimately, government-funded scientific research, as important as it

is, exists by taking the hard-earned money of taxpayers, who could use that money in countless other ways, to fund their health care, to send their kids to school, to pay for their house, you name it, and they take that money, we as government take that money from hardworking taxpayers, and we give it to scientists to conduct their studies. That seems to me to place a particular responsibility on the scientists who receive such funds. Simply put, if someone cannot explain why it is worthwhile to take another person's hard-earned money to do a study, maybe that study should not be done. And I know that is a strong principle, and I am passionate about science, but I believe scientists have a responsibility to recognize where the money comes from that funds their studies.

I also believe that because we have placed such a high premium and value on scientific research, it is especially incumbent upon the scientific community to hold themselves to the highest standards of integrity, objectivity, and honesty when reporting scientific information, not only to the Congress, but to the broad scientific community. We make important decisions based on the work of scientists, and the onus is on them to make sure their work merits that credibility.

I recognize fully that many times, scientific research at the initial stages is not always transparent, in terms of how it might be applied down the road, but I would urge all scientists, especially those receiving government funds, to ask themselves at some point: "How do I justify that to the crab fishermen on the Pacific Coast, or the logger in the mountains, or the farmer in Kansas, or the steelworker in Pennsylvania, who have given their money to fund my research?" And we will keep that in mind as we proceed through this Congress and through this committee.

I finally want to say this: I believe that one of the great things about science is it should not be partisan. Information, reason, informed discussion has no preference, necessarily, for one party or another. I have come to learn, since I have been in Congress, there are many good ideas on both sides of the aisle, and we should listen to them regardless of which side they come from. I have also come to believe there are many stupid ideas on both sides of the aisle, and we should evaluate them accordingly.

But on this committee, I will say to my friends, Dr. Ehlers, Mr. Hall, I look forward to working with you. If you folks have some things we can work on together, by all means, let us do it. And as we are working forward on issues coming from our side, we will approach you and see how we can make it better for everybody concerned.

So, thank you for your leadership, and with that, I want to say that, turning to today's testimony, I want to particularly welcome Congressman Hinojosa, who is appearing before us. He has introduced H.R. 524, a bill that would authorize the National Science Foundation to make matching grants to partnerships between high schools and institutions of higher education, business, or other community organizations, to explore ways to improve science labs for students. These grants will be used for teacher training and development, equipment and facilities, and curriculum development. The research and demonstration projects will be focused on improving labs at high schools serving large populations of students

under-represented in science and math careers today. Studies show it is these kids at the lowest rungs of the socioeconomic ladder, who are most lacking in this valuable learning experience.

How valuable is the lab experience for teaching science, and what is wrong with the labs in high schools now? The National Research Council brought attention to this issue in 2005 with their report, *"America's Lab Report: Investigations in High School Science."* The report presents an in-depth look at the problems plaguing the effective use of what many consider to be an integral part of learning science. To be sure, languishing facilities and old equipment are problems. The report, though, brings attention to the non-physical issues, such as inadequate teacher training and preparation, lab exercises not designed to fit with classroom curricula, and State science standards that are too extensive to actually allow time in the laboratory.

This subcommittee is devoted to improving science education, so devoted that we added science education to the name of the Subcommittee itself. We are concerned that American students are not achieving their potential in science and math education. It is a concern not only as we look at competing in a knowledge-based global economy for the high paying technology jobs, but at all levels of our economy. Folks need to have an understanding of science and math in order for them to succeed as individuals, and our nation to succeed as a country.

Improving K–12 science education is the ultimate key to the future prosperity and strength of our nation, as the National Academy pointed out in its report, *"Rising Above the Gathering Storm."* Improving K–12 education needs to be the keystone of any innovation agenda. I look forward to hearing from our witnesses today, and I want to recognize, now, Dr. Ehlers, for an opening statement.

[The prepared statement of Chairman Baird follows:]

PREPARED STATEMENT OF CHAIRMAN BRIAN BAIRD

Good afternoon. I want to welcome everyone and thank you for coming to this afternoon's hearing on *Improving the Laboratory Experience for America's High School Students.*

This marks the very first hearing of the Research and Science Education Subcommittee this Congress, and I want to take just a moment to express how pleased I am to be able to chair this particular subcommittee.

I want to thank Ranking Member Ehlers. He has been a true leader on the Science Committee and has extensive knowledge on the important issues that will come before this subcommittee over the next couple of years. I am pleased that he will be leading this subcommittee with me, and look forward to working with him closely.

I also want to acknowledge the great work of Congresswoman Eddie Bernice Johnson, who preceded me as the Democratic lead on this subcommittee. I intend to continue her commitment to math and science education, particularly in underserved communities, and am pleased that she has decided to continue her service on this subcommittee.

Long before I was a Member of Congress, I was a scientist. Long after I complete my service in this body, I will still be a scientist. Science is in my blood, it is part of my being. I value science not just for the astonishing discoveries and inventions it has produced, but as a method of making decisions and, in some ways, of leading one's life. Reason, informed by careful, critical evaluation of evidence, strikes me as the key not only to science, but to a successful personal life and—perhaps more importantly for our purposes here—to a successful republic. That view, as Members of this subcommittee will all know, was embraced by the Founding Fathers, many of whom were either practicing scientists in the world, or avid consumers of scientific research, as exemplified by Jefferson and Washington.

From that background, I approach the opportunity to chair this subcommittee with a mixture of profound excitement and some concern. Excitement—because this committee will have the opportunity and responsibility to address some of the core government programs that support much of the most advanced research being conducted anywhere in the world. To those of us who so passionately care about the scientific endeavor, and who see that endeavor as holding the keys to some of our most vexing national problems, this is a thrilling prospect.

At the same time, because I have spent time in the scientific field, I recognize that we scientists are not perfect and that there is room for improvement in the science community.

Ultimately, government funded scientific research takes the hard earned money of taxpaying citizens, money that those citizens could otherwise put toward paying for their own health care, for their homes, for their retirement, for their children's education, money that was not easily come by and is not easily parted with, and gives that money instead to scientists to pay for their research. Government funded scientists need to appreciate this fundamental sacrifice and, thereby, the responsibility it carries.

Simply put, if someone cannot explain why it is worthwhile to take another person's hard-earned money to do a study, maybe the study should not be done. That may seem shocking to say so directly, but I sincerely believe it is a matter of principle.

I recognize that in many instances, the government investment in science has paid off a thousand-fold in ways not easily imagined when the core research was being funded or conducted. At the same time, however, there is also much government funded research that provides very little return and yields only marginally used or applicable information. I recognize that there are no easy answers to these questions, but I think it is important that this subcommittee at least consider these questions as we move forward with our work.

I also believe that scientists who receive government money have a special responsibility to ensure that the research they perform with that money is consistent with the highest standards methodologically. Precisely because science and scientists are held in such high esteem by the public and policy-makers, I believe they bear a special responsibility for honesty, objectivity, rigor and integrity.

Finally, before turning to today's hearing, I wanted to say that I have always believed that there are good ideas on both sides of the aisle here in Congress. I very much want this subcommittee to operate in a bipartisan manner. I look forward to the input of Members of both parties as we work together to further the important work of this subcommittee.

Today, we'll be hearing testimony on the use of the laboratory experience in high school science classrooms. For a number of reasons, which we'll hear about today, this part of the science curriculum is currently in disarray across the country. I use the term "laboratory experience" rather than just "lab" because the challenge of effectively using a laboratory to teach students science turns out to be more difficult than just making sure we have enough Bunsen burners and beakers in every classroom.

I'd like to welcome Congressman Hinojosa who is appearing before us today. He has introduced H.R. 524, a bill that would authorize the National Science Foundation to make matching grants to partnerships between high schools and institutions of higher educations, businesses, or other community organizations to explore ways to improve science labs for students. These grants can be used for teacher training and development, equipment and facilities, and curriculum development. The research and demonstration projects will be focused on improving labs at high schools serving large proportions of students under-represented in science and math careers today. Studies show that it is these kids, at the lowest rungs on the socio-economic ladder, who are most lacking in this valuable learning experience.

How valuable is the lab experience for teaching science, and what's wrong with the labs in high schools now? The National Research Council brought attention to the issue in 2005 with their report, *America's Lab Report: Investigations in High School Science.* The report presents an in depth look at the problems plaguing the effective use of what many consider to be an integral part of learning science. To be sure, languishing facilities and old equipment are problems. The report, though, brings attention to the non-physical issues, such as inadequate teacher training and preparation, lab exercises not designed to fit with the classroom curriculum, and State science standards too extensive to allow time in the laboratory.

This subcommittee is devoted to improving science education—so devoted that we added science education to the name of the Subcommittee. We are very concerned that American students are not achieving their potential in science and math education. This is a concern as we look at competing in a knowledge-based global econ-

omy, and it's a concern when we look at being able to give every American an opportunity for those high-paying technology-based jobs. Improving K–12 science education is the ultimate key to the future prosperity and strength of our nation. As the National Academy pointed out in its report *Rising Above the Gathering Storm,* improving K–12 education needs to be the keystone of any innovation agenda.

I am looking forward to hearing from our witnesses today. Thank you.

Mr. EHLERS. Thank you, Mr. Chairman, and congratulations on your new post. We welcome you to that. I have always admired your honesty and your integrity in dealing with issues, and I totally agree with you. Science is not partisan. Science policy can be partisan, but the science itself should not be.

And I might just add an editorial comment, that I am upset at all those people who are trying to label the current White House as not being scientifically correct, and I recognize some members of the Administration might be, but I have watched Presidents over the years. Most of them are not very good at science. Most of them are not very good at using science, and I find it very disturbing that in spite of that record, and I don't think President Bush is any worse than anyone else who came along, probably somewhat better, but a pseudo-scientific group and certain scientists are trying to make science a partisan issue in the White House, and I don't think that is either helpful or appropriate.

Let me also say, picking up on your comment about justifying the use of taxpayers' money. I totally agree with you, and I remember Chairman Sensenbrenner's frequent questions, when he chaired the Full Committee of Science, and scientists would come to him and ask for money for their particular projects. His first question always was: "Have you talked to your Rotary Club about this?" And this just sets them back, "Why should I talk to my Rotary Club?" And his answer was simply: "If you can't sell it to your local Rotary Club, how do you expect me to sell it to the Congress." And that is the key point, all scientists should be out selling their particular work to the public, so they know it is being done, and the public will come to appreciate it.

Having said that, let me give a somewhat more formal statement. Laboratory experiences are a significant part of the greater issue of improving STEM education in our nation. U.S. science literacy is weak at the K–12 levels, compared to other countries, and our universities are burdened with a tremendous amount of remedial work in these areas. I am constantly on a mission to find ways that we can strengthen our system of education at all levels to incorporate support for STEM teachers and students, STEM of course standing for science, technology, engineering, and mathematics.

I am very pleased that my colleague, Representative Hinojosa, has introduced a bill to improve high school laboratory science, particularly for those in the highest need. I expect that the witnesses' reflections on laboratory science and the proposed legislation will be an invaluable part of the Committee process. There is clearly a need to improve upon high school laboratory experiences. One of the conclusions of the National Research Council's report on lab science was that educators and researchers do not agree on how to define high school lab science. This is a fundamental and necessary place to start. In fact, the NRC report found that there are such limited data on typical laboratory experiences that it is difficult to draw any conclusions about their effect on student learning.

The experts on the NRC panel scrutinized the strengths of integrated lab experiences, and discovered that a lab is only helpful when it is fully integrated into the learning process. Additionally, the report revealed that there is a dearth of research in this area, and students across the Nation could benefit from a study on the best way to establish a successful laboratory.

Let me also add a parenthetical note about why laboratory instruction is so essential today. A hundred and fifty years ago, over 90 percent of the people in this country lived on farms. And I don't know how many present have lived on a farm or worked on a farm. I grew up in a farming community, and every child who grows up on a farm learns physics by using the equipment on a farm. Today, only a small fraction of our population is on the farm, approximately two percent. That means 98 percent of our population is likely not experiencing the use of physics and physical equipment before they get into the schools, particularly high school, so it is essential for us to give them that experience that used to come with ordinary life, but no longer does.

Another aspect of this is that Nobel Laureate Carl Wieman, who has been working in this area for years now, in fact, has recently decided to work full-time on improving science education. During his tenure at the University of Colorado, he developed a physics educational technology project using simulations for both teaching and learning physics, and has made them freely available through a website. These simulations emphasize the connections between real life phenomena and the underlying science, and draw heavily on prior research findings.

Though Dr. Wieman's project was far from a traditional or even hands-on type of laboratory, the undergraduate physics students who used his simulations showed an increased mastery of concepts. In one of his research papers, Dr. Wieman concluded that "many physicists find it quite mysterious, and somewhat disturbing, that carefully developed simulations are more educationally effective than real hardware." In other words, simply saying we have to have laboratory experiments may not be the entire answer. It may not even be the correct answer. Perhaps simulations may be more effective. Again, that is something that should be studied.

As the National Research Council High School Lab Report also determined, I think that more evidence is necessary to determine what an effective laboratory looks like.

I look forward to the discussion about developing integrated laboratories and to learn from our witnesses. All of them have tremendous experience in the trenches, and I welcome them here today.

Thank you very much. I yield back.

[The prepared statement of Mr. Ehlers follows:]

PREPARED STATEMENT OF REPRESENTATIVE VERNON J. EHLERS

Laboratory experiences are a significant part of the greater issue of improving STEM education in our nation. U.S. science literacy is weak at the K–12 levels, and our universities are burdened with a tremendous amount of remedial work in these areas. I am constantly on a mission to find ways that we can strengthen our system of education at all levels to incorporate support for STEM teachers and students. I am very pleased that my colleague, Representative Hinojosa, has introduced this bill to improve high school laboratory science, particularly for those in highest need. I expect that the witnesses' reflections on laboratory science and the proposed legislation will be an invaluable part of the Committee process.

There is clearly a need to improve upon high school laboratory experiences. One of the conclusions of the National Research Council's Report on lab science was that educators and researchers do not agree on how to define high school lab science. This is a fundamental and necessary place to start. In fact, the NRC Report found that there is such limited data on typical laboratory experiences that it is difficult to draw any conclusions about their effect on student learning. The experts on the NRC panel scrutinized the strengths of integrated lab experiences, and discovered that a lab is only helpful when it is fully integrated into the learning process. Clearly, there is a dearth of research in this area, and students across the Nation could benefit from a study on the best way to establish a successful laboratory.

Nobel Laureate Carl Wieman has been working in this area for years now—in fact, he has recently decided to work full time on improving science education. During his tenure at the University of Colorado, he developed a Physics Education Technology project with simulations for teaching and learning physics and has made them freely available from a website. These simulations emphasize the connections between real-life phenomena and the underlying science, and drew heavily on prior research findings. Though Dr. Wieman's project is far from a "traditional"—or even "hands-on" type of laboratory, the undergraduate physics students who used his simulations showed an increased mastery of concepts. In one of his research papers Dr. Wieman concluded that "Many physicists find it quite mysterious and somewhat disturbing that carefully developed simulations are more educationally effective than real hardware."[1] As the National Research Council High School Lab Report also determined, I think there is a lot more work necessary to determine what an effective laboratory looks like.

I look forward to the discussion about developing integrated laboratories, and to learn from our witnesses. All of them have tremendous experience "in the trenches," and I welcome them here today.

Chairman BAIRD. Thank you, Dr. Ehlers. If there are any other Members who wish to submit additional opening statements, your statements will be added to the record.

At this time, I would like to introduce the witness for our first panel, Congressman Rubén Hinojosa from Texas, the author of H.R. 524. Rubén, we are pleased to have you appear before us today to talk about your bill.

I now recognize my friend from Texas for his testimony.

## Panel 1:

### STATEMENT OF HON. RUBÉN HINOJOSA, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF TEXAS

Mr. HINOJOSA. Good afternoon. Is the microphone on? I would like to thank Chairman Baird and Ranking Member Ehlers and all the Members of the Subcommittee for giving me the opportunity to present testimony on a pressing need: access to high quality laboratory science in our high schools.

I would especially like to thank my fellow Texan, Congresswoman Eddie Bernice Johnson and Chairman of the Full Committee, Congressman Bart Gordon, for their advice and support in developing H.R. 524, the *Partnerships for Laboratory Science Act,* better known as PALS, which we are here to discuss today.

I would like to express my appreciation to the STEM education community, particularly the chairs of the STEM Education Coalition, James Brown of the American Chemical Society, and Jodi Peterson of the National Science Teachers Association, for their advocacy on behalf of opportunities for our young people, and for their commitment to ensuring that we do not lose future scientists and

[1] *Physics Today,* November 2005, pp. 36–40

engineers because they did not get preparation in laboratory science in high school.

We have major holes in our pipeline for preparing future professionals in science, technology, engineering, and math, better known as the STEM fields. None is more glaring than the lack of preparation for college level work for the students graduating from high schools that have high concentrations of poor and minority students.

The National Science Foundation commissioned a study by the National Research Council on the state of America's high school labs. I would like to draw your attention to two glaring findings in that report.

One, the current quality of laboratory experiences is poor for most students, and educators and researchers do not agree on what constitutes an adequate high school laboratory, hampering the accumulation of research on how to improve labs.

The second finding, schools with higher concentrations of non-Asian minorities and schools with higher concentration of poor students are less likely to have adequate laboratory facilities than other schools.

Mr. Chairman, I ask unanimous consent that the rest of my statement be included in the record, because I would like to speak from personal experience of what I have seen in the good laboratories and in the poor ones.

I come from an area in South Texas that is 250 miles south of San Antonio. The area is 80 percent Hispanic, and an area that has for too many years been neglected. We didn't see a sitting President in that area from 1953 to 1998, for 45 consecutive years. Shameful. Big neglect.

So, I can tell you that the area is now progressing, because we have been investing in human capital, in education of public schools, in colleges and universities, and other infrastructure projects that are helping that area prosper.

But I want to share with you that we have the South Texas Independent School District with five magnet schools, two of which are listed in the top 1,000 high schools in the country. The Math and Science Academy is in the top ten, and has been for three consecutive years, and then, the Allied Health is a magnet school that is really focusing on allied health careers, and nursing, and we have produced a lot of practicing medical doctors.

And the important thing is that we focused a great deal on the science labs. Why? Because, as one of the members of the Education Committee, here in Congress, I went to visit Thomas Jefferson High School, and that is in Northern Virginia, and always among the top producers of National Merit Scholars. It is amazing that they can produce 70 semifinalists for that designation, and that out of those 70 semifinalists, 40 got the National Merit Scholarship, and so, that is proof that what I am going to say makes a big difference, and that is that when I took a delegation from the Math and Science Academy of South Texas, there were about ten men and women who work there, the Superintendent, several of the Professors, and several school board members, and we noted that their laboratories was the most exciting thing that the students had in their rigorous educational program. You couldn't get

a job at that school, because nobody wants to quit. They had teachers with Master's and Ph.D.s, and the students, you couldn't get them out, because they had such exciting projects.

All this to say that we know that it works, because we now have two schools in the top 100 in the Nation, an area that has more migrant children than any other region in the country, and when they featured it one of the business periodicals, it was interesting that they selected a child from a migrant family who scored 1500 on her SAT, and so good are the SATs and ACT scores that they are recruited from the best Ivy League schools in the country, East Coast to West Coast, full scholarships and 97 percent of their graduates are going on to college.

Folks, there is no doubt in my mind that we are on the right track with this legislation. I am pleased to tell you that in just a short while this afternoon, less than 45 minutes, I gathered 40 cosponsorships to add to the original 30 sponsors of this legislation for a total of 70 bipartisan Members of Congress thinking why, or asking me, what has taken you so long?

Also, I am pleased to report to the Committee that Senator Menendez over in the Senate side is offering the mirror legislation that we have in the House, and so, I believe that we just simply need to raise the level of awareness of the condition of our science labs, and get the appropriators to build up some courage and invest in our high school labs, and I think that things are going to really improve.

With that, Mr. Chairman, I yield back the balance of my time.

[The prepared statement of Mr. Hinojosa follows:]

PREPARED STATEMENT OF REPRESENTATIVE RUBÉN HINOJOSA

Good Afternoon. I would like to thank Chairman Baird and Ranking Member Ehlers and all of the Members of the Subcommittee for giving me the opportunity to present testimony on a pressing need—access to high quality laboratory science in our high schools.

I would especially like to thank my fellow Texan, Congresswoman Eddie Bernice Johnson and the Chairman of the Full Committee, Congressman Bart Gordon for their advice and support in developing H.R. 524, the *Partnerships for Laboratory Science Act,* which we are here to discuss today.

I would also like to express my appreciation to the STEM Education community, particularly the chairs of the STEM Education Coalition, James Brown of the American Chemical Society, and Jodi Peterson of the National Science Teachers Association for their advocacy on behalf of opportunities for our young people and for their commitment to ensuring that we do not lose future scientists and engineers because they did not get preparation in laboratory science in high school.

We have major holes in our pipeline for preparing future professionals in science, technology, engineering, and mathematics—the STEM fields. None is more glaring than the lack of preparation for college level work for students graduating from high schools that have high concentrations of poor and minority students.

The National Science Foundation commissioned a study by the National Research Council on the state of America's High School Labs. I would like to draw your attention to two glaring findings in that report:

1. The current quality of laboratory experiences is poor for most students and educators and researchers do not agree on what constitutes an adequate high school laboratory, hampering the accumulation of research on how to improve labs.
2. Schools with higher concentrations of non-Asian minorities and schools with higher concentrations of poor students are less likely to have adequate laboratory facilities than other schools.

Here are some other things that we know:

- Last spring the American Council on Education issued a report, *Increasing the Success of Minority Students in Science and Technology,* which identified lack of a rigorous high school curriculum as a major barrier to completing a college degree in the STEM fields.
- The latest science report card included an astonishing figure—only one in four Black or Hispanic students take the three major laboratory sciences—biology, chemistry, and physics—that are the foundation for future STEM work in college.

With these types of statistics, it should come as no surprise that we are losing our competitive edge in producing experts in math, science, and engineering. We must redouble our efforts to engage young people in these fields early in their academic careers. As we look at a broad based, national innovation or competitiveness agenda, we need to bring in partners to address this part of the pipeline.

That is why I introduced the *Partnerships for Access to Laboratory Science Act.* This legislation will establish a pilot program that will partner high need school districts with colleges and universities, and the private sector to improve high school laboratories as part of a comprehensive plan to improve science instruction and student learning outcomes.

This pilot is intended to develop models and test effective practices for improving laboratory science in high need schools. It will leverage resources from the local community and the private sector, and it will build on our base of knowledge of what works in teaching science. The legislation is a logical next step forward from the National Research Council's report on high school labs.

Our next generation of scientists and engineers are waiting to be discovered in our nation's high schools. Let's make sure that our schools are equipped to provide them with the laboratory experiences they need to develop their talents and foster a life-long interest in science. This is something that we can accomplish together.

Thank you for allowing me to testify today. I would be happy to answer any of your questions.

Chairman BAIRD. I thank the gentleman, and unless there are any urgent questions on any Members of the Committee, as is the custom, we will excuse the gentleman and thank him very much for his testimony, for his leadership on this.

You speak with great passion and experience, and we would hope that we could, in all of our districts and across this country, replicate the kind of successes you have described.

Thank you very much, Rubén, for your leadership on this.

Mr. HINOJOSA. Thank you much, sir. Thank you.

Chairman BAIRD. At this time, I would like to introduce the witnesses on our second panel, and if Mr. Hinojosa wishes to stay, he is of course welcome to. If he needs to go, we understand that as well.

First is Dr. Arthur Eisenkraft, a Distinguished Professor of Science Education and Director of the Center for Science and Math in Context at the University of Massachusetts in Boston. He also served on the National Research Council committee that authored *"America's Lab Report: Investigations in High School Science."*

Next is Ms. Linda Froschauer, President of the National Science Teachers' Association. She is also the K–8 Science Department Chair for the Weston Public Schools of Weston, Connecticut.

And Dr. Jerry Mundell is a chemistry Professor at Cleveland State University in Cleveland, Ohio, where he serves as coordinator of the Freshman Chemistry Committee.

I would remind our witnesses that spoken testimony is limited to five minutes each. You have got those little lights there. My dear friend, Dr. Ehlers, and when he was Chair, reminded people that at the yellow light, you should pay close attention, because when the light turns red, a trapdoor emerges beneath your chair, and you will disappear from view. We have modified that. It will still

apply to the witnesses. It now also applies to the Members as well. When we exceed our time commitment, there is a trapdoor, and we will be gone two floors down and picked up by maintenance later in the day.

But seriously, we look forward very much to the testimony. You have done some great work. We look forward to hearing about it, particularly in the concept of the outstanding legislation introduced by Mr. Hinojosa.

Dr. Eisenkraft, please.

## Panel 2:

**STATEMENT OF DR. ARTHUR EISENKRAFT, DISTINGUISHED PROFESSOR OF SCIENCE EDUCATION; DIRECTOR, CENTER OF SCIENCE AND MATH IN CONTEXT (COSMIC), UNIVERSITY OF MASSACHUSETTS, BOSTON**

Dr. EISENKRAFT. As the spring baseball and softball season begins, I thought it would be good to take a moment to imagine two teams getting ready for this season. Both teams have fans and baseball players and good coaches, and one of them gets to practice with bats and balls, and gets on the field, and the other gets to watch videotapes and learn and read books about baseball. And we have to wonder, which team would you rather have your child on? Who is going to do better this season?

Well, it is a silly question to ask, because the answer is obvious. You want the team who can practice, and yet, the same situation, a parallel situation exists today in our high school labs, where some students get the opportunity to investigate the processes of science by doing science, others get to hear about science, listen to people talk about science, and perhaps watch videotapes.

The National Research Council of the National Academy of Sciences produced this study at the request of the National Science Foundation. Eight of my colleagues and some staff members worked on this for a good amount of time, and we agreed on a definition of laboratory experiences, and we looked at the goals and effectiveness of labs in America.

The legislation considered here corresponds to two of the conclusions reached here, related conclusions. One was that labs on the whole are not doing what we thought they would be doing. They are poor in most respects. And also that, in spite of how poor those labs are, children in poor communities aren't even getting those labs, and children who are lower in academic ability in affluent school districts are not getting those labs, either.

So, why do we care about lab experiences? Why are the poor quality of labs and the unavailability of labs to segments of our population concerns? So, no amount of watching other people do science is an adequate substitute for doing science one's self. For 25 years, I have watched my wife. She takes these two sticks, and she goes like this, and then a sweater pops out after a certain amount of time. And now, I have watched this for 25 years with care, and what are the chances, you think, if you gave me some yarn and some knitting needles, I could make a sweater? Well, most people don't give me a 50/50 chance or even a 10 percent chance. Only the kindest of people give me a one percent chance.

Most people say you have no chance, and yet, we think, though, that students can watch somebody else do science, and they will be able to figure out. If I can't do it with knitting a sweater, I don't think they will be able to do it by doing that. That is one reason we have labs, to provide these experiences to students.

But the other reason is related to the common experience. There was a study in the *New York Times* three years ago which showed the learning, the television viewing habits of black and white Americans. Out of the top ten television programs, only two were in common on both lists. What that meant to me was that every time I give a television reference in class, I was disenfranchising students in the school who were not like me. That same thing exists in all segments of our society, so every textbook in science talks about waves in the harmonic oscillators or whatever, and they all say like the waves at the beach. Well, I will tell you there are kids in Boston and kids in Los Angeles who have never been to the beach, and it is only five miles from their house. So, I have no idea what kids in Nebraska are thinking when they read in the book like the waves at the beach.

What we do in the lab is we give people a tub of water, they slosh it back and forth. They make observations, they make measurements, they draw conclusions based on that, so that we don't have to assume that the only people who have an understanding of this are the ones who were lucky enough to vacation at the beach in some part of their lives. We need these kinds of experiences in order to level the playing field of all the students.

Once we figure out that we need labs, we have to figure out how to do them better. How do we integrate them into the instructional units? How do we make them meaningful? How do we give them a context? How do we use the best learning from the cognitive psychology research in order to help them?

If Olympic teams were performing as poorly as our students are in international competitions, there would be a national cry for more attention, for improved coaching, for more opportunity, for better equipment. We should have the same sense of urgency for our students. Instead of just being science students, they can be student scientists.

Thank you very much.

[The prepared statement of Dr. Eisenkraft follows:]

PREPARED STATEMENT OF ARTHUR EISENKRAFT

As the spring baseball and softball season approaches, we can take a moment to imagine two teams getting ready to begin their season. Both teams have energetic players, dedicated coaches and supportive fans. Both teams have playing manuals, novel strategies and team building exercises. The only difference between the teams is that one practices using bats, balls and gloves while the other team listens to lectures and watches videotapes of professional players. If you wanted your children to win, which team would you put them on?

While it seems silly to think that some parents would want their children to play a sport without actually practicing, we have created a similar scenario in our high school science classrooms. Students in some classrooms investigate the processes of science by performing experiments, making measurements and drawing conclusions from this data. Students in other classrooms read about the processes of science, listen to stories about how experiments are conducted, and watch videotapes. If we want our children to be good scientists, which classrooms should we put them in?

The National Research Council of the National Academy of Sciences recently completed a study entitled, *"America's Lab Report: Investigations in High School*

*Science"* at the request of the National Science Foundation. I had the opportunity to serve on that committee along with nine other colleagues and staff members of the NRC. The committee agreed on a definition of laboratory experience, reviewed the research on the goals and effectiveness of laboratory experiences in our high schools and arrived at a number of conclusions that are all relevant to this committee's deliberations.

The first conclusion of the committee focused on the need to create a definition of laboratory experience to insure that we agree on the instruction we are describing and in order to assist the research community in future studies. The committee's agreed-upon definition that *"Laboratory experiences provide opportunities for students to interact directly with the material world (or with data drawn from the material world), using the tools, data collection techniques, models and theories of science"* includes studies of friction on inclined surfaces, of how metals react with acids and observations of a drop of water with a microscope. It also recognizes that some laboratory experiences do not permit students to record data but instead involve analyzing data from large databases. For example, science researchers study climatic change by reviewing data recorded over the past centuries rather than recording this data themselves. It also does not restrict laboratory experiences to a lab room and includes field experiences where researchers study the ecology of deserts or rain forests.

The committee also culled from the research a list of goals of laboratory experiences which includes:

- Enhancing mastery of subject matter;
- Developing scientific reasoning;
- Understanding the complexity and ambiguity of empirical work;
- Developing practical skills;
- Understanding the nature of science;
- Cultivating interest in science and interest in learning science; and
- Developing teamwork abilities.

The legislation being considered by the Committee includes references to the third conclusion of the study and a related concern: that "[t]he quality of current lab experiences is poor for most students," and "[s]tudents in schools with higher concentrations of non-Asian minorities spend less time in laboratory instruction than students in other schools, and students in lower level science classes spend less time in laboratory instruction than those enrolled in more advanced science classes."

Why do we care about lab experiences in high school classes? Why are the poor quality of labs and the unavailability of labs to segments of our population concerns?

No amount of watching other people do science is an adequate substitute for doing science oneself. For 25 years, I have watched my wife take two sticks and bang them back and forth and to and fro and then a sweater pops out. I really have watched at times with interest and fixed attention. What are the chances that you could give me knitting needles and some yarn and I would produce a sweater? Most people tell me that there's not a 50/50 chance, not even a 10 percent chance. Only the kindest people give me a one percent chance while most people give me no chance at all. If I cannot knit a sweater after watching my wife knit for 25 years, why do we expect that our science students will be able to conduct experiments when they have only observed teacher demonstrations at a distance or, even worse, have only viewed pictures of experiments in textbooks?

In addition to teaching students how to do science, laboratory work also creates a common experience among the students that can be used to improve discussions and increase achievement. *The New York Times* published an article listing the top ten most viewed television programs by whites and blacks in America. There were only two programs that appeared on both lists. The important message from that study is that every time I used a television reference in class, I disenfranchised students who are not like me. When I mentioned a specific popular television program in order to engage the students or provide an analogy, some students did not understand the reference. In most science books about waves, the author describes harmonic motion using the example of waves at the beach. While you and I have seen the ocean, many students in Boston and Los Angeles have never been to the beach and it is only five miles from their home. What is a student in Nebraska able to understand when the text reference is to the waves at the beach? In our wonderfully diverse schools and society, we cannot assume that everybody has seen the same TV programs or the same movies; we do not go to the same churches or go on the same vacations; we do not have the same experiences. The laboratory provides a

place where students can observe water waves, measure water waves and draw conclusions about water waves. It provides a common experience for all students and, in that way, levels the playing field and provides all students an entry into the science lesson and does not limit that entry to students who have been fortunate enough to have vacationed at a beach.

Once we are convinced of the need for lab experiments in schools, then we must also address the quality of those labs. The NRC report is quite clear that the "typical" lab does not meet the goals of laboratory experiences while the "integrated instructional unit" does. With respect to laboratory experiences, the "integrated instructional units" should provide for exploration of what prior knowledge students bring to the classroom. The lab should then have them compare and contrast their prior knowledge with the results of their laboratory investigation. The lab should not be taught in isolation, but should relate to a larger unit of study. "Just because students *do* a laboratory activity, they may not *understand* what they have done." Moving teachers toward this more viable approach to labs requires teacher training—both pre-service and in-service. Teachers and curriculum developers should apply the following "four principles of instructional design," as enumerated in the report, to make the lab experiences "achieve their intended goals."

1. "[the labs] are designed with clear learning outcomes in mind,
2. they are thoughtfully sequenced into the flow of classroom science instruction,
3. they are designed to integrate learning of science content with learning about the processes of science, and
4. they incorporate ongoing student reflection and discussion."

The present-day "typical" lab doesn't produce the intended goals of labs because the lab is often not part of a successful instructional sequence. The "typical" lab is sometimes presented before the discussion of the related concepts while other times it is presented weeks after the concept is discussed. Many times the lab is delayed until the lab room or equipment becomes available. The "typical" lab often asks students to follow a set of 'cookbook' instructions and does not mirror the inquiry aspects that can help students learn about and experience the processes of science.

In contrast, the "integrated instructional unit" follows the design principles outlined above. The labs are used to provide experiences to students prior to having them provide explanations of those experiences. The teacher role is to help students make sense of their data and their explanations and to assist the students in coordinating their observations with accepted scientific content and understandings.

Many science frameworks require that students understand the concept of density. If you were to pick up a traditional textbook, you may find the following paragraph: *Density explains why rocks sink and wood floats. Density is defined as the mass divided by the volume. D = M/V. Let's do a problem: A piece of wood has a mass of four grams and a volume of five cm³. Calculate the density.* The text then goes on to solve this sample problem followed by a more difficult one where the mass and density are given and the student is required to calculate the volume. Students may learn the definition of density and be able to solve such problems, but have no idea why density is important or why we study it. They may or may not then go to the lab to actually make measurements of mass and volume and apply the definition. And, if they do go to the lab, they often engage in a "typical" lab where the steps are outlined and the purpose is to confirm what they have been told. Student misconceptions related to density are rarely addressed. An alternative approach to this concept is used in *Active Chemistry,* an NSF-supported high school science curriculum. Students are first asked to compare a kilogram of feathers and a kilogram of lead. This helps teachers to gauge their students' prior understanding of the concepts. The students then conduct an investigation where they measure the mass and volume of different amounts of water. When they divide the mass by the volume, they find the ratio is always $1 g/cm^3$. They repeat the same investigation with alcohol and find that the new ratio is always $0.79 g/cm^3$. They repeat the same investigation with clay and find the ratio is now always $2.6 g/cm^3$. Students are then asked the question, "If someone were to tell you the mass and volume of a material, could you determine if it were water, alcohol or clay." Students easily respond, "Sure. You divide the mass by the volume. If the ratio is one, it's water; if the ratio is 0.79, it's alcohol; and if the ratio is 2.6, it's clay." When the teacher asks, "But what if I had only a small amount of the material?" the students respond, "Oh the amount doesn't matter. We know that because we tried it many different times with different amounts and the ratio always stays the same." The teacher can then explain that because of its importance, we give this ratio a name—we call it density. Density is a characteristic property of matter. It's one way in which we can deter-

mine if you have a diamond or glass ring or whether something is solid gold or gold-plated. Of course, the students then complete problems with calculations as required on exams. In this approach, the concept emerges from the students' experiences in the high school lab. The activity precedes the concept introduction and the concept precedes the introduction of vocabulary. This more closely mirrors how science evolves. Scientists do not invent words and then hope that these words will be linked to important and meaningful concepts. Unfortunately, too many science texts and science programs approach science in this way. In the preferred approach to density, students explore their prior understandings, find patterns in the data, draw conclusions about the importance of the ratio of mass to volume and then return to compare and contrast these findings with their prior understandings. In the *Active Chemistry* unit where this concept is introduced, students must also transfer this content knowledge to a new domain where they have to apply the concept of density to the creation of a special effect for a movie.

A large part of the NRC study surrounded the question of whether labs are effective means of instruction. In other words, do high school labs make a difference? After a careful review of the literature, the committee attempted to respond to this question by looking at each of the goals mentioned above. The review was complicated by the lack of a coherent definition of laboratory experience across the studies. In addition, many of the studies did not control for all variables nor did they take into account how other factors may affect performance. Other confounding factors also made the task of literature review and drawing conclusions from this review difficult.

What the Committee was able to conclude was that the "typical laboratory experiences" did not meet the goals we have for lab investigations while the "integrated instructional units" showed promise in meeting the majority of the goals.

With regard to the first goal, mastery of subject matter, "exposure to these integrated instructional units leads to demonstrable gains in student mastery of a number of science topics in comparison to more traditional approaches." Specifically, "In physics, these subjects include Newtonian mechanics (Wells, Hestenes and Swackhamer, 1995; White, 1993); thermodynamics (Songer and Linn, 1991); electricity (Shaffer and McDermott, 1992); optics (Bell and Linn, 2000; Reiner, Pea, and Shulman, 1995); and matter (Lehrer, Schaubl, Strom, and Pligge, 2001; Smith, Maclin, Grosslight, and Davis, 1977; Snir, Smith, and Ra, 2003). Integrated instructional units in biology have enhanced student mastery of genetics (Hickey, Kindfield, Horwitz, and Christie, 2003) and natural selection (Reiser et al., 2001). A chemistry unit has led to gains in student understanding of stoichiometry (Lynch, 2004)."

With regard to the second goal of developing scientific reasoning, typical laboratory experiments can help students improve on some of the aspects of scientific reasoning but fall short in assisting students in formulating research questions or designing experiments. In contrast, once again, integrated instructional units can assist students in developing all aspects of scientific reasoning. "They can learn to design experiments (Schauble et al., 1995; White and Fredericksen, 1998), make predictions (Friedler, Nachmias, and Linn, 1990), and interpret and explain data (Bell and Linn, 2000), and interpret and explain data (Bell and Linn, 2000; Coleman, 1998; Hatano and Inagaki, 1991; Meyer and Woodruff, 1997; Millar, 1998; Rosebery, Warrren, and Conant, 1992; Sandoval and Millwood, 2005). Engagement with these instructional units has been shown to improve students' abilities to recognize discrepancies between predicted and observed outcomes (Friedler et al., 1990) and to design good experiments (Dunbar, 1993; Kuhn et al., 1992; Schauble et al., 1995; Schauble, Klopfer, and Raghavan, 1991).

With regard to goal three, developing practical skills, there has been very little specific study in either typical lab experiences or in integrated instructional units. One study did show that girls handle lab equipment less frequently than boys and this is associated with less interest and less self-confidence in science ability in girls.

The remaining goals—understanding the nature of science, cultivating interest in science and interest in learning science, and developing teamwork abilities—follow a similar pattern. The research results are not uniformly consistent in whether the typical lab experiences or the integrated instructional units help students achieve these goals. However, it appears that the integrated instructional units show greater promise than the typical lab experiences.

From the evidence on the effectiveness of labs, the committee recommends that specific design principles mentioned earlier can help laboratory experiences meet their intended learning goals. In addition, the committee concluded that "a serious research agenda is required to build knowledge of how various types of laboratory

experiences (within the context of science education) may contribute to specific science learning outcomes."

The introduction of a lab program into a high school is an expensive venture. Lab facilities and equipment require capital expenditures. The replenishment of supplies requires additional annual funds. In addition, safety requirements place limits on the number of students that can be properly supervised in a classroom. Too often, administrators ask teachers to accept unsafe conditions by packing too many students in the lab space. When teachers object, the administrator may suggest that we sacrifice the quality of teaching by not providing lab experiences at all. This Hobson's choice forces teachers to make a bad decision—unsafe conditions or poor instruction. In contrast, high schools across the United States support football teams that similarly require large expenditures for equipment and subscribe to required safety requirements. The football coach is never asked to use sub-standard helmets or to cancel play. High school science should not be considered less important than high school football.

Michael Faraday is arguably the most accomplished experimental physicist of the 19th century. Living as a poor boy in England, Faraday was apprenticed at a young age to a bookbinder. After little schooling and meager math skills, Faraday went on to solve the largest puzzle of his time—how to produce electricity. He accomplished this because of his access to laboratories and his hard work and true talent for experimentation. What would happen to a Michael Faraday in American schools today? As a poor student, he may attend an urban school where there are no labs. As a student with few math skills, he may be enrolled in a science class for underachieving students with no laboratory period. Either way, today's Faraday is denied the opportunity to discover his extraordinary talents in the laboratory and our society is impoverished as a result.

We must provide labs to high school students in order to give them experience with the processes of science in much the same way that I have to practice on knitting needles in order to make a sweater. We have to provide labs to students so that they have a common experience with which to explore science content. And we must insure that all students have equal access to labs regardless of their socio-economic status or whether they are enrolled in an honors class or a remedial class. These labs should reflect what we know about effective, high quality lab instruction as well as what we know about student learning.

If Olympic teams were performing as poorly as our American students are in international competitions, there would be a national cry for more attention, for improved coaching, for more opportunity, and for better equipment. We should have the same sense of urgency for our students. Instead of just being "science students," they can be "student scientists."

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Citations for all research studies quoted here can be found on pages 108–115 of *America's Lab Report.* The text can be accessed at *www.nap.edu*

### BIOGRAPHY FOR ARTHUR EISENKRAFT

Arthur Eisenkraft is Distinguished Professor of Science Education at the University of Massachusetts, Boston, where he also directs the Center of Science and Math in Context (COSMIC). He previously taught physics and served as science coordinator in New York public school districts for 28 years. He is a Past President of the National Science Teachers Association and has been involved in a number of its projects, creating and chairing the Toshiba ExploraVisions competition and the Duracell science scholarship competition. He is Project Director of *Active Physics,* an NSF-supported curriculum project, which is introducing physics instruction for the first time to all high school students. He is also Project Director of *Active Chemistry.* He initiated U.S. involvement in the International Physics Olympiad, was Academic Director for the first eight teams and then served as the Executive Director of the XXIV International Physics Olympiad in 1993 when the United States hosted the competition for forty participating countries. He holds a U.S. patent for an improved vision testing system using Fourier optics. At the National Research Council, he was a member of the curriculum working group that helped develop the National Science Education Standards, the Committee on Learning Research and Educational Practice, the Committee on Attracting Science and Mathematics Ph.D.s to K–12 Edu-

cation, and the Committee on Assessing Technological Literacy. He is a fellow of the American Association for the Advancement of Science (AAAS), a recipient of the Presidential Award for Excellence in Science Teaching (1986) and the Disney Science Teacher of the Year (1991). He has been recognized for his contributions to science education by the American Association of Physics Teachers (AAPT), the American Physical Society (APS) and the National Science Teachers Association (NSTA). He has a B.S. and M.A. degrees from Stony Brook University and a Ph.D. from New York University.

Chairman BAIRD. Ms. Froschauer.

**STATEMENT OF MS. LINDA K. FROSCHAUER, PRESIDENT, NATIONAL SCIENCE TEACHERS' ASSOCIATION; K–8 SCIENCE DEPARTMENT CHAIR, WESTON PUBLIC SCHOOLS, WESTON, CONNECTICUT**

Ms. FROSCHAUER. Thank you for this opportunity to present testimony on behalf of the National Science Teachers' Association. I am Linda Froschauer, and I am the President of NSTA. I am also an eighth grade science teacher and Science Department Chair in Weston, Connecticut, and I have been a science teacher for over 32 years now.

The National Science Teachers' Association is committed to promoting excellence and innovation in science teaching and learning for all, and we provide our members with a variety of resources and support, including high quality professional development, publications, networking opportunities, and curriculum materials.

NSTA strongly supports H.R. 524 and the Partnerships for Access to Laboratory Science grants. We applaud the Science Committee for realizing the importance of high school laboratory experiences, and for its leadership and dedication to this issue. The PALS legislation would create a pilot program at NSF to study the best ways to train teachers in lab instruction, the best way to set up staff and manage labs, and ensure that those labs have the best possible equipment, materials, and supplies. The PALS bill will help fill our gaps in knowledge in a way that will make it possible for a large range of schools to benefit from the results of the pilot research program.

So, why is PALS necessary? A 1995 report from the U.S. General Accounting Office, titled *"School Facilities: America's Schools Not Designed or Equipped for the 21st Century,"* found that 42 percent of all schools surveyed nationally reported they were not at all well-equipped in the area of laboratory science. A second GAO report in 2005, titled *"Federal Science, Technology, Engineering, and Mathematics Programs and Related Trends,"* found that approximately 40 percent of those college students who left the science fields reported some problems related to high school science preparation. The under-preparation was often linked to problems, such as not understanding calculus, and the lack of laboratory experience.

We know we have many challenges ahead in our efforts to reform and strengthen the science education that we provide to students. For science to be taught properly and effectively, labs must be an integral part of the science curriculum. But in many schools, lab science is done poorly or not at all.

Several days ago, we asked NSTA members via email to tell us about the lab experience in their school. Hundreds of teachers told

us about the poor state of the lab facilities and instruction in their schools, and the challenges that they face in providing a quality lab experience for students.

This urban teacher wrote: "In my urban, inner city school, I teach a lab science in an old business room. There are no tables, benches, water, or gas service, no sinks, fire extinguisher, eyewash stations, fire blankets, or any other equipment." Another teacher told us: "I have no specific safe area in which to conduct labs. My yearly budget is the same as it was 12 years ago. I must purchase all of my equipment and supplies. I have no safety equipment other than a portable eyewash station and a fire extinguisher. My district claims that labs are extracurricular and not mandated by my subject. My kids are accustomed to labs using kitchenware or materials I have purchased at Wal-Mart. They have no idea how to use scientific equipment or even what it looks like due to lack of funding."

This biology teacher wrote: "I have been teaching high school biology for ten years. I have old microscopes that I could actually swap out for Coke bottles and not even notice the difference. However, the greatest problem I see is my lack of skill in the area of lab investigations. I agree that this is the best source of learning that my kids can get, but I simply don't have the skill to design these labs. Safety is a huge concern. We do not have any rooms to use as actual laboratories. Although we have lots of equipment, we have no place to safely use it, and few teachers who know how to use it. Currently, the one room that had been a lab is used by teachers to sell hot chocolate and nachos to students to raise money for trips to Washington, D.C., for a very small group of students. The lab cannot be used as a lab. They removed the tables, and replaced them with desks."

And finally, we heard this from a teacher who confesses about his own shortcomings in the classroom: "I have not learned how to facilitate real thinking and essential planning for authentic lab experiences. I don't know what students really need in an introductory chemistry experience at the high school level, and I cannot figure out how to teach logical thinking and sequencing to over 20 students in a lab at the same time."

In conclusion, H.R. 524 partnership grants can be instrumental in helping schools to develop and maintain a safe, well-equipped lab space, and bring ongoing professional development to teachers.

Thank you.

[The prepared statement of Ms. Froschauer follows:]

PREPARED STATEMENT OF LINDA K. FROSCHAUER

Mr. Chairman and Members of the Committee

Thank you for this opportunity to present testimony on behalf of the National Science Teachers Association. My name is Linda Froschauer, and I am President of the NSTA. For 32 years I have been a science teacher and I am currently an 8th grade science teacher and Department Chair at the Weston Public Schools in Connecticut.

The National Science Teachers Association is committed to promoting excellence and innovation in science teaching and learning for all. We offer members a wide variety of resources and support, including high quality professional development, publications, networking opportunities, and curriculum materials.

NSTA strongly supports H.R. 524 and the Partnerships for Access to Laboratory Science grants. We applaud the Science Committee for realizing the importance of

high school laboratory experiences and for its leadership and dedication to this issue. As you well know core competencies in STEM are absolutely vital to our nation's future in this global economy. American schools must cultivate the finest scientists, engineers, and technicians—from every part of our society—so that we can create the innovations of tomorrow that will keep our nation strong.

The PALS legislation would create a pilot program at NSF to study the best ways to train teachers in lab instruction; the best way to set up, staff, and manage labs; and ensure that labs have the best possible equipment, materials, and supplies. The PALS bill will help fill in our gaps in knowledge in a way that will make it possible for a large range of schools to benefit from the results of the pilot research program.

Science educators are firmly committed to the role of the laboratory in the teaching and learning of chemistry, physics, biology, and earth sciences. The American Chemical Society is similarly committed to quality laboratory experiences: their *Guidelines for the Teaching of High School Chemistry* states "the laboratory experience must be an integral part of any meaningful chemistry program. ACS recommends that approximately thirty percent of instructional time should be devoted to laboratory work."

The American Association for the Advancement of Science Project 2061 *Designs for Science Literacy* states "Learning science effectively. . .requires direct involvement with phenomena and much discussion of how to interpret observations."

NSTA has a position paper on laboratory science which was developed with a great deal of input from the National Research Council's report *America's Lab Report, Investigations in High School Science.* Both NSTA and the NRC believe that quality laboratory experiences provide students with opportunities to interact directly with natural phenomena and with data collected by others. Developmentally appropriate laboratory experiences that integrate labs, lecture, discussion, and reading about science are essential for students of all ages and ability levels.

Throughout the process, students should have opportunities to design investigations, engage in scientific reasoning, manipulate equipment, record data, analyze results, and discuss their findings.

If done correctly quality lab experiences are an important part of inquiry and help students to understand the natural world. NSTA recommends that all pre-K–16 teachers of science provide instruction with a priority on making observations and gathering evidence, much of which students experience in the lab or the field, to help students develop a deep understanding of the science content, as well as an understanding of the nature of science, the attitudes of science, and the skills of scientific reasoning (NRC *America's Lab Report,* 2006, p. 127).

Lab investigations should not be a rote exercise where students simply follow directions, as though they were reading a cookbook. Properly designed laboratory investigations should:

- have a definite purpose that is communicated clearly to students;
- focus on the processes of science as a way to convey content;
- incorporate ongoing student reflection and discussion; and
- enable students to develop safe and conscientious lab habits and procedures (NRC *America Lab Report,* 2006, p. 101–102).

Unfortunately, we know that laboratory science is a high-priced luxury beyond the reach of far too many public high schools. A 1995 report from the U.S. General Accounting Office, titled *School Facilities: America's Schools Not Designed or Equipped for the 21st Century,* found that 42 percent of all schools surveyed nationally reported that they were **not at all** well-equipped in the area of laboratory science. In addition the report found that:

- 43 states reported that one-third or more of their schools met functional requirements for laboratory science **not well at all.**
- 49 percent of schools with a minority student population greater than 50 percent reported meeting functional requirements for laboratory science **not well at all.**
- Over 48 percent of schools where 40 percent of the student population qualified for free or reduced lunch reported meeting functional requirements for laboratory science **not at all.**

A second GAO report in 2005 titled *Federal Science, Technology, Engineering, and Mathematics Programs and Related Trends* found that "In addition to teacher quality, students' high school preparation in mathematics and science was cited by university officials and others as affecting students' success in college-level. . .. Researchers found that "approximately 40 percent of those college students who left the science fields reported some problems related to high school science preparation.

The under preparation was often linked to problems such as not understanding calculus; lack of laboratory experience or exposure to computers; and no introduction to theoretical or to analytical modes of thought."

NSTA is also very concerned about the equity issue involved with the high school laboratory experience. It is imperative that all students—including students with academic, remedial, or physical needs; gifted and talented students; and English language learners—have the opportunity to participate in laboratory investigations in a safe environment.

We know we have many challenges ahead in our efforts to reform and strengthen the science education we provide to students. We agree with Representative Hinojosa that "Our next generation of scientists and engineers are waiting to be discovered in our nation's high schools. Let's make sure that our schools are equipped to provide them with the laboratory experiences they need to develop their talents and foster a life-long interest in science." To quote American Chemical Society President Dr. Katie Hunt, "Simply put, when science is taught well with adequate resources, it can capture imaginations."

For science to be taught properly and effectively, labs must be an integral part of the science curriculum. H.R.524 is a positive step forward in developing quality lab experiences for all students.

Many schools would benefit from this pilot program and the research that it will bring. To get a sense of the current situation with high school labs, on March 5 we asked NSTA members via e-mail, *"What are the problems with the lab experience in your school?"*

Hundreds of teachers told us about the current state of the lab facilities and instruction in their schools and the challenges they face in providing a quality lab experience for students:

- In my urban, inner city school, I teach a lab science in an old business room. There are no tables, benches, water or gas service, sinks, fire extinguisher, eye-wash stations, fire blankets, or other equipment. In addition, while there is a high rate of attrition towards the end of the year, each September starts with 50 students in each class.
- I have no specific, safe area in which to conduct labs. My yearly budget is the same as it was 12 years ago. I must purchase all my own equipment and supplies. I have no safety equipment other than a portable eye-wash station and a fire extinguisher. My district claims labs are "extracurricular" and not mandated by my subject. My kids are used to labs using kitchenware or materials purchased at Wal-Mart. They have no idea how to use scientific equipment or even what it looks like due to a lack of funding.
- I have been teaching high school biology for ten years. I have old microscopes that I could swap for coke bottles and not notice a difference. However, the greatest problem I see is my lack of skill in the area of lab investigations. I agree that this is the best source of learning that my kids can get, I just simply do not have the skill to design these labs. IF the NSTA wants to make a change in science education, THIS is where it should be done. . .TRAINING.
- My high school building was built in 1970. The budget for yearly supplies has not changed in the six years I have been here. I have a supply budget of $750 per year. I teach between three and four science subjects per year seven classes per day, two of them being chemistry and physics. I have absolutely no supplies to teach electricity and magnetism or optics. My chemistry supplies are even worse. My lab facilities are set up for physics, but I am expected to teach chemistry in low benches. I don't know a chemist who will use a Bunsen burner sitting down. Hence, I do not teach the labs that require Bunsen burners because I feel it is unsafe to use the burners in my room. I also do not have a ventilation hood in my room.
- We do not have any rooms to use as actual laboratories. Although we have lots of equipment, we have no place to safely use it and few teachers who know how to use it. Currently the one room that had been a lab is used by teachers to sell hot chocolate and nachos to students to raise money for trips to Washington, DC, for a very small group of students. . .the lab cannot be used as a lab. . .they removed the lab tables and installed desks for all the students.
- I have not learned how to facilitate real thinking and essential planning for authentic lab experiences. I don't know what students really need in an introductory chemistry experience at the high school level, and I cannot figure out

how to teach logical thinking and sequencing to 20+ students in lab at the same time. My time management skills are lacking. There's much more, too.

- I teach chemistry and Earth science in a room with six lab tables; it was originally designed to be a physics lab room. There is electricity to the tables, but it doesn't work. There are not sinks, therefore no eye-washes; there are no gas outlets. The sink at my instructors table has the water turned off and the gas turned off. We were given a budget of $5000 for each department last year, but the orders were not filled because. . .who knows? I have not received the supplies I ordered for eight out of the last 10 years. When I first took over this class-lab room and associated storeroom, there was a great amount of equipment and glassware and old kits and a little of everything. It is not possible to do any other than the most elementary labs at this school. It would be unsafe and probably criminally liable to attempt most chemistry labs. The fire extinguisher doesn't work.
- While I do not teach high school science currently but do teach in a two-year community college, I see many students entering with virtually no lab experience. While some students come quite prepared, it's very frustrating for me to have students coming into a college biology class with no knowledge of basic lab equipment and techniques, such as using beakers, graduated cylinders, pipettes, or even basic microscopy skills.
- Our school does not provide enough funding for lab experiments. In addition, senior members of the department do not believe that other than AP students and some honors classes—should have access to lab experiments. Therefore the classes I teach—college bound and special education—have little to no money that goes towards lab science in the Biology classroom. Furthermore, the set up of the classroom also is a problem when it comes time to do lab experiments.
- I teach biology in a portable without any sinks, no storage, and only four outlets. It's such a challenge to put together a real lab. My portable is far away from the real science labs so it's hard to even get materials over here. There's no prep area out here so I have to go to one of the main buildings to prep. Yet those prep rooms are not easily accessed if you don't have an attached classroom. My room has carpet so I am reluctant to use many chemicals because they are difficult to clean up if spilled.
- Our school has minimal funding for improving the quality of lab sciences. Individual teachers are encouraged to write for grants using their own time without pay. Three of our four science rooms do not have eye-wash stations or proper venting equipment. There is no interest in funding the purchase of electronic data collection equipment/computer based labs by the administration. Little effort is made in our district to train teachers to improve the quality of lab experiments and the necessary follow-up assessment.
- Several things need to be addressed. (1.) The large amount of time to get a lab ready, carried out and cleaned up. Teachers need more time or a paid lab assistant. (2.) The equipment and supplies are lacking due to inadequate budgets. (3.) I was not trained or shown how to conduct labs. I had to learn it on my own. (4.) Students have never been taught how to behave in a lab. They think it's playtime not learning time. (5.) Six teachers share one lab. Scheduling is a major problem.
- We do not have adequate materials for labs at our school. We have one set of materials for each discipline (Earth science, biology, chemistry and physics) and five or six teachers trying to use the materials for their class. The budget for our science department (high school of about 1,900 students and growing) is $6,000/year.
- Besides funding for lab science, my own school has 1964 construction, which means, the science rooms were built in a time when the accepted teaching method was direct instruction and not inquiry based learning. There is no space for ongoing projects.
- If this country is serious about educating our children in science, then we need to provide designated laboratory teachers and updated equipment to these 50-year-old facilities. Administrators need to be adequately trained or have someone who is, to give advice and support. Each school needs a lab budget, and not be dependent on the pockets of the struggling teacher.
- I am our district's K–12 science coordinator and have taught high school for many years in our district and in other districts. The two biggest problems I see (and hear from other teachers) too many students in classes and not

being supported financially. Some principals feel science is too expensive. Currently due to the lack of support our AP Chemistry labs are taught by the classroom teachers at the local university.

- I teacher upper middle school Science. We have NO equipment to do Science labs. Our school is five years old and no equipment was bought when the school was built. There is no way I can I do labs without the basic equipment. The students beg for lab work but I have to say no because lack of funding.
- In our school district, the quality of lab experiences are hindered by the large class sizes (36 in a class). Along with the large class sizes comes unsafe conditions, including lack of space. A number of teachers also lack lab experience and are not qualified to lead labs correctly. Our district would benefit from teacher trainings on lab experience and labs that meet State standards.
- The major problems are lack of storage space for equipment and lack of funds to repair equipment or replace equipment with more modern and student accessible equipment.
- When our building was redesigned, a dedicated room for chemical storage was left off of the plans. We have had to divide our chemical stockroom among three prep rooms, which after two years are still not equipped with the storage and safety features needed. The rooms designated for Chemistry do not have fume-hoods installed, making it hard to do many of experiments safely. In addition, a majority of our science classes have at least 30 students in a classroom, with some lab classes having between 40 and 50 students in one classroom. With poor organization of resources, a large student-to-teacher ratio, chemistry teachers not highly qualified to teach the subject, and numerous safety issues, labs become exceptionally difficult to do.
- My district has newly refurbished laboratories. I am qualified to supervise labs as I have both industry and academic experience in chemistry. However, even though the lab is set up to safely accommodate 24 students, the school administration insists this is just a guideline and insists of overcrowding the labs with up to 28 students. This makes it hazardous for the students, as they are crowded together. It also makes it hard for me to supervise the students, especially in classes where there are students with IEP's or other learning issues. One teacher cannot safely supervise that many students in a lab involving chemicals, hot plates, burners, and glassware. In fact, in a class with multiple IEP's, twenty four students is too many for one teacher to supervise. There needs to be a maximum of students per teacher (allowing for weighting of students with IEP's) in a lab environment, or schools should hire lab aides to help teachers if that number is exceeded.
- Many teachers in my district, which is well-funded and well equipped, lack the confidence to conduct lab experiences. They most often have poor classroom management and therefore believe that the students would not practice safety and that someone could be injured. Another factor is several science teachers are also coaches and therefore will not conduct lab experiences with their students because coaching takes priority over instruction. They say that they don't have time to set up the labs.
- I believe lab science should play a key role in science education. Our main problem is lack of funding. We are not allowed to charge lab fees and our budget is $3,000 for 1,500 students (seven teachers). Over half of our budget is used for paper (copies) so less than $1,500 is available for science. That doesn't buy much. It limits not only what we do but also limits the use of technology in science. We have highly qualified teachers to teach labs but not the funds to support them. We just recently cleaned closest to literally get rid of the old equipment from the 1950's and 1960's which was the last time we had large amounts of funding.
- We are assigned 37+ students per class making it difficult if not impossible to provide worthwhile safe laboratory experiences. Additionally, the lack of preparation time and no lab technician support means if a science teacher wants to provide his/her students with a laboratory experience he/she must work late into the evening to properly prepare.
- Most of the problems center around getting the individual teacher to accept that labs are integral to the understanding of science. Most of our freshmen science teachers do not want to bother with setting up the lab equipment or monitoring students while they do the lab. It's much easier to maintain control while the students are in their seats taking notes.

- I teach Chemistry and Physics at a Catholic High School. We are hampered by a lack of resources. I have lots of glassware and other materials that do not wear out, but when I came here last year we had no chemicals. I have ordered a bare minimum of chemicals, but our budget is small. Physics is in a little better shape, but most of the equipment is circa 1970's.
- We currently have three chemistry labs for seven teachers, one physics lab for three teachers, and five biology labs for eight teachers. Class sizes frequently are 30+ students for biology, 26+ for chemistry, and 24+ for physics. The main problem we face is lack of space and time to do labs. Our classes are overcrowded to the extent that the chemistry teachers have cut back on labs due to safety concerns. Our class time for labs has been cut from 74 minutes to 48 minutes in all general and honors classes, and this also impacts ability to do labs, especially as we share lab space with other teachers. To compound these issues, in 2008 we are bringing the 9th grade into the high school (we are currently 10–12), and this will add about 700 students into the building who will all be required to take lab science classes. We as a staff have no idea how we are going to manage this. Many of us are doing paper "labs" and computerized lab activities because of our safety concerns.
- I love labs, but I am not given very much money to spend. Last year I was able to purchase several LAB-Aids kits. This year I was not allowed to purchase refill kits for them. The schools should be forced to allow a set amount of money for the purchase of equipment and supplies. I can't afford to pay out-of-pocket. I took over physics this year. It has been taught as a math class for several years. I asked for lab equipment and was turned down.
- Maybe I am in the minority but we have a fantastic situation. Our district just remodeled our science labs. We have a great space and good equipment. Our district not only supports but encourages science.
- We do not have the funds needed to do labs as we should. I am lucky if I get to do one or two actual labs for each of our seven units. We do lots of hands-on activities, but they just aren't the same as experimentation.
- In the past we have had funding for the equipment but recent budget cuts have prevented us from buying the annual consumables, so the equipment just sits there.
- I am currently an 8th grade Science Teacher and attempting to be as much help to High School Science Teachers as I can. I have taught for 30 years and have watched as funding, lab facilities and equipment have declined. As a Middle School teacher we could assist the high school with preparation for the science experience of all students, however our funding has been drastically cut along with the liability issues of labs. Simple science is difficult when we cannot even use pond water and are now required to purchase expensive purchased samples or pre-prepared slides. If science suppliers would assist with some financial breaks for the middle schools it would help our cause. I am sitting with microscopes which we cannot use, aquariums that remain empty as districts take a close look at liability of mold, mildew and ventilation.
- As a private school, we have all the necessary equipment and materials to run excellent labs. All our teachers are trained as lab instructors, and we make sure even the general students perform labs at least three times a month. That being said, teenagers do tend to push the limits at every chance. I have at least five "firebugs" who look for opportunities to do something dangerous. Consequently, constant vigilance is required. It is exhausting to set up, and most set-ups need to be refreshed between classes. However, the nature of science requires lab experiences for a true inquiry approach. I can see why school systems would get rid of labs altogether, relying on on-line simulations, but it is certainly worth the effort. Perhaps having a specific lab instructor who would run and maintain the labs, similar to a college environment, would work.
- Current situation: one biology lab, 22 bio classes; one chemistry lab, 19 chemistry classes; no physics lab; bio and chem labs are unsafe, run-down, ill-equipped. Future (2007): new science wing to be built, 15 lab/classroom combos, fully equipped and technologically up-to-date; science educators expect science education here to go from mediocre at best to hands-on, interactive, interesting, creative, . . .a very positive experience. There is a definite need for professional development in science labs. Today's teachers have so little experience because of the conditions offered at most public high schools.
- One of the biggest problems I have faced in my teaching is that I have too many students in my room to safely do lab activities. I have one room with

the lab area around the perimeter of the room and desks in the middle of the room. I have so many students in my room that the desks are pushed right up next to the lab counters on all sides. To do any activity where the students need to stand at the lab benches, the desks need to be pushed to the center and then there is not enough room for all students to stand at the counters together. In teaching the physics portion of 9th grade physical science I am fortunate that I have not had a lab that uses the gas, I would be quite hesitant to do so in this room because I do not believe it could be done safely. There is no recourse in my district for the number of students in my class; in fact I have heard that next year they are going to try to put more in my room. Due to this space constraint, I have done fewer lab activities.

- Our primary hurdles are lack of funds and equipment. Since we are a small, rural district with limited industry and local income, our budget for the entire science program is $1200. This is barely enough to replace consumables in chem, phys sci, and biology, much less order the more expensive equipment. In addition, emphasis is more readily placed on math and English as these are the primary areas of standardized testing. Additionally, our class size is sometimes such that labs must be limited due to space and safety issues. For the most part, our science teachers do a good job of implementing labs to the best of our ability.
- As a suburban district in an affluent community, we have very frequent lab opportunities—we have lab activities two to four times per week in biology. We recognize the importance of laboratory experience and are limited primarily by time available.
- Actually—we have a wonderful lab experience for our middle school. One day a week we have students for 80 minutes to do lab—this is balanced against their history class—so on the alternate day they have history for 80 minutes. Works well and our kids leave having a good grasp of good laboratory practices.
- My middle school does not have a lab. I have to use two desks side by side to get a large enough flat area so students can do what I call desk-top labs. Money of course is also a problem so to get around that I sometimes ask students to bring in items from home such as different liquids so we can use them to test for pH. I sometimes have students work in groups of four to cut back on expenses when the ideal would be to work in groups of two. Due to lack of space in the classroom, labs requiring extended observation time can't be done. So students complete these as at-home experiments. I require them to bring in the evidence to prove the task was actually done along with a completed lab guide. I avoid dangerous chemicals and use votive candles if flames are necessary.
- We have a wonderful lab science program for our 7–12 grade students. It is set-up as a college model with a full-time lab instructor who preps, runs, and grades the lab work. Lab procedures are consistently followed, and students know what to expect. Labs are scheduled on a regular basis since classroom teachers do not have to make time to set-up/take-down labs.
- The biggest obstacle to providing quality lab experiences for science students in my high school is funding. The budget simply does not allow for in depth or multiple labs. We must pick and choose which labs to do, which is often determined by which labs are the cheapest. I feel that we are doing a disservice to our kids in this area.
- Science labs used to meet for a double lab period once a week. That got cut in the 90's at many schools due to mandated testing for education reform. It is very difficult to run a lab investigation in a 45-minute or one hour format. You end up carrying it into the next class and losing the point. Also many science or lab aid position have been cut requiring teachers to do all prepping, make solutions, order supplies, etc. This is very time consuming never mind grading, planning and of course teaching.
- As a chemistry teacher I am, as expected, adamantly in favor of integrating laboratory experience into my curricula. I am fortunate in that I work in a high school with a once spectacular laboratory facility that was for over 20 years maintained by a trained laboratory technician. Four years ago that technician's position was cut, and since then the state of our lab has declined. Routine maintenance of equipment as well as preparation for every experiment is left to the instructors; in effect, doubling or tripling our work, depending on the experiment performed. Given these conditions, many teachers have opted to eliminate many of the more challenging experiments their students

once performed. Wouldn't it be great if we science teachers received a check in the mail to spend on equipment rather than a half nod and a heap of rhetoric from our elected officials?

- No money for lab supplies. . .I buy almost all my lab supplies out of my own pocket. . .and there is very little equipment. . .I improvise all the time, using recycled bottles and jars from home, and plastic cups from the supermarket.
- My chemistry lab is very outdated and worn out. The space provided is nowhere near the suggestions for science lab classrooms today. There is only one exit which has 22 desks between it and the lab area. I have to constantly fight to keep my eye-wash and shower working "just in case!" The drains leak and are wrapped with towels, which is someone's idea of preventing slow leaks. It is very much inadequate, but that doesn't keep me from doing a lot of lab work. I just try to keep it very benign as much as possible. It would be GREAT to have a renovated lab. I have done research and put in the request, but funding is tight and it is just not in the school's budget.
- I know the materials I want/need to teach my content, but I am inhibited by unnecessary (way stricter than State standards) safety requirements for chemicals by my district, lack of funding for equipment, disinterest by district administrators in providing resources for "regular" (not honors) classes. And it was only last year that safety equipment (proper eye-washes, showers. . .) were installed in the classrooms. I didn't have those in my prep room. The fume hoods don't all work. The lab benches aren't bolted to the floor and get bumped around easily. THERE ARE TOO MANY KIDS IN MY CLASSES.
- I agree that lab science is a much-needed partner with other science deliveries. In my school, I try to do at least one lab a week (either myself or as a class). Our school was built in 1954; there are many experiments that simply aren't safe in our laboratory. We have no fume hoods and ventilation is poor at best. Also, I am given a $1,000 budget per year to spend on all classroom consumables including chemicals. I can only order (restock) certain chemicals every year as ordering just 30 items would put me over budget.
- Though we are lacking some supplies, for the most part we have the bulk of items that we need to do basic experiments. However, many teachers do not do them for lack of understanding the science and fear of labs with "tough," hard-to-teach kids. Labs take a lot of teacher effort, especially labs that work (like inquiry). Many of my colleagues are not held accountable for the lab component; therefore, they do not do the lab component.

In conclusion, H.R. 524 partnership grants can be instrumental in helping schools to develop and maintain a safe, well-equipped lab space and bring ongoing professional development to teachers. Research-based pilot programs will help fill in the gaps in our knowledge about how best to employ labs. The best practices and materials developed in this pilot program can be used as a model by stakeholders who want to strengthen high school lab science in their communities. We call on Congress to support this innovative legislation to improve science education.

## Biography for Linda K. Froschauer

*National Science Teachers Association President, 2006–2007*

Linda K. Froschauer, K–8 Science Department Chair at the Weston Public Schools, in Weston Connecticut, is President of the National Science Teachers Association (NSTA). She began her one-year term on June 1, 2006.

Froschauer has been a devoted teacher and dedicated leader in science education. She began her teaching career as an elementary school teacher in Matteson, Illinois; moved on to middle level teaching at the Greenwich Public Schools, in Greenwich, Connecticut; and has been with the Weston Public Schools since 1985. She combines her work in the classroom with a leadership role in her school, serving as grades K–8 Science Department Chair/mentor teacher. Outside the classroom she has worked as an instructor for Chicago's Museum of Science and Industry; as a writer/consultant for many publications; and as a field editor, reviewer, and consultant for numerous organizations.

For more than 30 years, Froschauer has been a leader and active member of NSTA. In 1976, she was named the first Preschool/Elementary Division Director to serve on the NSTA Board of Directors. She later worked on many NSTA committees, including the International Convention Planning Committee, the Preschool/Elementary Committee, and the Informal Education Committee, and she has chaired

both the Awards and Recognition Committee and the Committee on Nominations. She also has served as Middle Level Division Director, worked on the Committee and Board Operations Task Force, and led the development of NSTA's first Family Science Day, which was held in conjunction with the NSTA National Convention in Boston.

Froschauer's devotion to science education is evidenced by her involvement in numerous other professional organizations. She has served as President of the Connecticut Science Supervisors Association (CSSA), the National Middle Level Science Teachers Association (NMLSTA), and the Council for Elementary Science International (CESI). She is also a member of the Connecticut Academy for Education in Mathematics, Science, and Technology; the Association of Presidential Awardees in Science Teaching; and the Society of Elementary Presidential Awardees. She has been actively involved in Project 2061, a national effort to improve science education sponsored by the American Association for the Advancement of Science.

Froschauer was chosen as a Connecticut Science Educators Fellow and named Weston Teacher of the Year in 1999. Her other awards and accomplishments include receiving the NSTA Distinguished Teaching Award, Middle Level, in 2001; National Board for Professional Teaching Standards certification, also in 2001; the CSSA Charles Simone Award for Outstanding Leadership in Science Education in 1998; a Presidential Award for Excellence in Mathematics and Science Teaching in 1993; and the Educational Press Association of America's Distinguished Achievement Award in 1991.

Froschauer earned a BS degree in education from Northern Illinois University, an MA in science teaching from Governors State University, and a sixth-year degree in curriculum and supervision from Southern Connecticut State University.

Chairman BAIRD. Dr. Mundell.

## STATEMENT OF DR. JERRY MUNDELL, PROFESSOR OF CHEMISTRY, CLEVELAND STATE UNIVERSITY

Dr. MUNDELL. While preparing my testimony for the Subcommittee, I decided to confront my general chemistry class with some background questions concerning their high school laboratory experiences. My survey consisted of several questions, to which the 66 students responded with their clickers. Here are some samples of the questions and their responses.

"Did the lab portion of your high school course help you to better understand chemical concepts?" 44 percent agreed. "Did the lab portion of your high school chemistry course stimulate your interest in chemistry?" Now, only 33 percent agreed. And finally, "Did the lab portion of your high school chemistry course help to prepare you for your college chemistry course?" Only 21 percent agreed.

Early in my career, first as an industrial research chemist with the Lubrizol Corporation, and later, while working on my doctorate degree at Case Western, I found laboratory routine and research the most vibrant part of my work. Whether it was a problem involving chemical synthesis or the employment of investigative techniques to characterize substances, the physical pursuit of the science was always pulling me back into the laboratory. It is the nature of this physical pursuit which can inform and sometimes enlighten, and within the proper setting, such as a high school laboratory, even provide opportunities of growth and inspiration.

Traditionally, these opportunities do not occur in the normal experiences found in high school science labs, which are highly structured around classical laboratory techniques and chemical syntheses. It should be our chief concern to replace these traditional high school lab exercises with experiences of exploration and discovery. With the participation of local colleges and universities, such laboratory experiences may be developed and readily accessible to area high school students.

An example of such a program is now ongoing at Cleveland State University. CSU is participating in a five year, NSF-funded program which provides such opportunities for its undergraduate students. The Research Experience to Enhance Learning Program, which is REEL, addresses the issue of student experiencing the discipline of chemistry through participation in actual research situations. Instead of performing a series of lab experiments listed on a syllabus, the students learn to design and execute green chemistry experiments performed on local environmental samples.

During the course of the semester, students utilize many of the topics covered in the corresponding general chemistry lecture, in addition to advanced laboratory instrumentation and techniques unavailable to students enrolled in traditional general chemistry lab courses.

The assessment at the end of the course is based on individual PowerPoint presentations of each student's research, accompanied by their written write-ups. Students also are encouraged to publish in research journals such as *Journal of Undergraduate Research,* as well as making presentations at the real chemistry symposiums and local ACS meetings-in-miniature.

Although this particular program is set up on the university campus, with additional funding and proper training of school teachers, this type of program could be offered at a secondary school level. Within this type of laboratory experience, students are soon to acquire a sense of ownership of the subject. Participating in actual research situations instills maturity in students. They are no longer just learning for the grade, but instead, applying their knowledge to real life problem solving, but this depth of experience, for students would only come, with a similar depth of commitment from the teachers.

In conclusion, I strongly support House Bill H.R. 524, especially subparagraph (B), article 5, which identifies a need of funding for professional development and training for teachers.

As important as supplies, equipment, and well-constructed laboratories are in the implementation of a valuable teaching program, I strongly believe that the failure of our high school students to successfully participate in college level science curriculum is, in part, due to our failure to inspire them. This inspiration can only come from well-informed teachers with strong attachments to their subjects. Good science teachers need to be well-grounded in their turf. They need opportunities outside of the normal coursework to continually develop not only as teachers, but also, as scientists, and this can evolve by building closer associations between the secondary school teachers and the college and university research faculty.

By implementing programs which enable school teachers to actively participate in summer research opportunities within their research, area universities and high school teachers would better be able to appreciate and understand the nature of science.

Thank you.

[The prepared statement of Dr. Mundell follows:]

PREPARED STATEMENT OF JERRY MUNDELL

My position with the Chemistry Department at Cleveland State University (CSU) has provided me the opportunities to assess the status and effect of high school science laboratory instruction from two perspectives: 1) the performances of the students, both prior to and as they enter into post secondary science education; and 2) the information I have received either directly from public school teachers whom I have taught as part of the Ohio Teaching licensure program or those teachers I have interacted with in several CSU/Cleveland School programs. Although most of my teaching at Cleveland State University has been involved with students enrolled in freshman chemistry courses, I have had many occasions to instruct high school students *(CSU Upward Bound Summer Program),* Middle School Teachers *(Mathematics and Science Partnership)* and High School Teachers *(Cleveland Teaching Leadership Program).* Through these interactions with both students and teachers, including my participation in programs such as the regional *Northeastern Ohio Center for Excellence, NEOCEx,* and the CSU funded *9–16 Committee,* I believe myself to be adequately prepared to both comment and recommend on the subject of the importance of science laboratory experience in the education of high school students.

While preparing my testimony for this subcommittee, I decided to put the numbers and studies aside for a moment and indulge the thoughts of those primarily affected by this situation. Instead of starting the 8:30 lecture with a graded quiz question projected on the two screens at the front of the lecture hall, I confronted my general chemistry class with some background questions concerning their high school laboratory experiences. My survey consisted of several questions, to which the students would respond with their "clickers" (i.e., electronic personal response transmitters).

Of the 66 students who participated in the survey 85 percent took a high school chemistry course which contained a laboratory component. Although 79 percent of those students felt that their lab instructors were well informed, only 62 percent believed the lab instructions were clear and comprehensive, and only 56 percent thought the labs were well equipped. Having addressed the instruction and equipment aspects of the courses, I used the final three questions of the survey to summarize their high school lab experiences:

1) *Did the lab portion of the course help you to better understand chemical concepts?* (44 percent agreed);
2) *Did the lab portion of your high school chemistry course stimulate your interest in chemistry?* (33 percent agreed);
3) and finally, *Did the lab portion of your high school chemistry course help to prepare you for your college chemistry course?* (21 percent agreed).

Although this survey only represented a minor population of all those CSU students enrolled in the College of Science, the results parallel the current national trend of students receiving substandard or insufficient high school science laboratory experience. Although I presently do not have the tools to accurately quantify the success or failure on individual high school chemistry lab courses, I do have first hand experience with incoming freshmen who generally lack the sufficient interest or skills to properly engage in a college chemistry course.

Each fall semester, the final grades of my General Chemistry course reflect approximately 25 percent of the class receiving letter grades of D, F, or W (a withdrawal from the course). The *2006 Book of Trends,* published by Cleveland State University, indicates similar final grades in other freshman science courses: College Chemistry courses (Chemistry for non-science majors) with 33–36 percent of the class receiving letter grades of D, F, or W; and entry level Biology courses with similar results. Results which indicate that 25–36 percent lack the sufficient foundation in science to successfully compete in post secondary science courses.

Similar trends are occurring at the university level at CSU. As an urban university, consisting of 18 percent Black and two percent Hispanic student enrollments, retention rates of 41 percent and 36 percent respectively are of much concern.

In a response, to better prepare high school students for the academic challenges of post-secondary education, CSU has aligned itself to the teachers in primary and secondary institutions by participation in grant programs designed to better prepare the public school students for post-secondary education:

1) *Teaching by Inquiry: Nature of Science, Academic Standards, and Supervising of Instruction.* PI: Dr. Frank Johns, Professor Emeritus, College of Education, Cleveland State University.

   Teaching secondary school principals to observe and evaluate science lab teaching.

2) *Partners for Success.* PI: Dr. Joann Goodell, Associate Professor, College of Education, Cleveland State University, and Facilitator: Dr. Robert Ferguson, Assistant Professor, College of Education, Cleveland State University.

   Augmentation of content knowledge and including laboratory experience. The program consists of four meeting sessions over the academic year and a one week session during the summer, with a two commitment by each cohort.

3) *Urban Stream Scholars.* PI: Dr. Robert Ferguson, Assistant Professor, College of Education, Cleveland State University, and Dr. Michael Walton, Associate Professor, College of Science, Cleveland State University.

   This program trains secondary school teachers to perform science labs and incorporate research methods and hands-on activities into the classroom (start-up date: summer 2007).

4) *Mathematics and Science Partnership.* PI: Dr. Joann Goodell, Associate Professor, Cleveland State University.

   CSU is working in collaboration with Youngstown University, John Carroll University, and the University of Akron to educate both Middle School and High School Teachers in the content of laboratory training in the sciences.

5) *NEOCEx.* PI: Dr. Joann Goodell, Associate Professor, College of Education, Cleveland State University; CoPI: Dr. Roland Pourdavood, Associate Professor, College of Education, Cleveland State University.

   Northeastern Ohio Research Center for Excellence consists of four universities: Kent State University, University of Akron, Youngstown State University, and Cleveland State University. The focus of the research is to understand and interpret how the Learning of Science and Mathematics effects high school students' attitudes and disposition toward science.

Throughout my years as a teacher of freshman chemistry, I had tried various ways of engaging the interest and commitment of my students enrolled in one of the traditional lab courses with varying degrees of success.

An instructive laboratory exercise doesn't need to be costly, dangerous, or steeped in convoluted instructions and incomprehensible scientific concepts. With a laboratory balance, a package of toy balloons, and a three dollar package of dry ice, I have conducted the following exercise in an ordinary classroom and illuminated a couple dozen students about the nature of gas behavior, the function of proportionality constants, the implication of significant figures, and the importance of group work.

Before conducting the exercise, the students break into groups of three and each group receives a balloon. The groups are instructed to record the mass of the balloons before the instructor places approximately one gram of dry ice into the balloons. The groups then tie off the end of their balloons before recording the mass of the balloons containing the dry ice. After the dry ice has completely sublimed and the balloons are completely inflated the groups are instructed to measure and record the circumferences of the balloons.

With the mass of the dry ice and the circumference measurements, students are instructed to 1) calculate the volume of the balloons using the proper numbers of significant figures, and 2) determine the value of the proportionality constant in the equation relating the volume to the mass of dry ice. Another sample of dry ice in a weighed balloon is given to each group. Using the derived equations, each group is instructed to calculate the expected volume their balloon should produce. Finally, the calculated volumes are compared to the resultant volumes.

I have presided over this exercise in classrooms of high school students, classrooms of college students, and classrooms of school teachers with similar positive results in all.

The high school laboratory experience can also be set up with real research situations in which the students learn to function and think as scientists. Early in my career, first as an industrial research chemist with the Lubrizol Corporation and later while working on my doctorate degree at Case Western Reserve University, I found laboratory routine and research the most vibrant part of my work. Whether it was a problem involving chemical synthesis or the employment of investigative techniques to characterize substances, the physical pursuit of the science was always pulling me back into the laboratory. It is the nature of this physical pursuit which can inform, and sometimes enlighten, and within the proper setting, such as a high school laboratory, even provide opportunities of growth and inspiration.

Traditionally these opportunities cannot be found in the normal experiences found in high school science labs, which are highly structured around classical laboratory techniques and chemical synthesis. These exercises although instructive, don't motivate or inspire. It should be our chief concern to replace the traditional high school

lab exercises with experiences of exploration and discovery. With the participation of local colleges and universities, such laboratory experiences maybe developed and readily accessible to area high school students.

An example of such a program is now ongoing at CSU: The Chemistry Department of Cleveland State University is participating in a five-year NSF funded program, which provides such opportunities for its undergraduate students. The *Research Experience to Enhance Learning* program addresses the issue of students experiencing the discipline of Chemistry through participation in actual research situations. Instead of performing a series of lab "experiments" listed on a syllabus, the students learn to design and execute green chemistry experiments performed on local environmental samples. At this time, the focus of the work is on the presence of PAH, polyaromatic hydrocarbons—pollutants that exist in the Cleveland community. During the course of the semester, students utilize many of the topics covered in the corresponding General Chemistry lecture in addition to advanced laboratory instrumentation and techniques unavailable to students enrolled in traditional general chemistry lab courses. The assessment at the end of the course is based on individual Power Point presentations of each student's research accompanied by their written reports. Students are also encouraged to publish their research in the *Journal of Undergraduate Research* as well as making presentations at the REEL Chemistry symposiums and local ACS Meetings in Miniature.

Although this particular program is set up on a university campus, with additional funding and proper training of school teachers, this type of program could be offered at a secondary school level. Within this type of laboratory experience, students are soon to acquire a sense of ownership of the subject. Participating in actual research situations instills maturity in students. They are no longer just learning for the grade, but instead applying their knowledge to real life problem-solving. But this depth of experience for the students would only come with a similar depth of commitment from the teachers.

In conclusion, I strongly support House Bill H.R. 524 goals of enhancing the teaching of laboratory teaching in the high schools. Of the articles under subparagraph B, article v, which identifies the need of funding for *professional development and training for teachers.* As important as supplies, equipment, and well constructed laboratories are in the implementation of a viable teaching program, I strongly believe that the failure of our high school students to successfully participate in college level science curriculum is, in part, due to our failure to inspire them. This inspiration will only come from well informed teachers with strong attachments to their subjects. But I further recommend that a continuous series of science courses will not remedy this situation. Good science teachers need to be well grounded in their turf. They need opportunities outside of the normal course work to continually develop not only as teachers, but also as scientists. And this can evolve by building closer associations between the secondary school teachers and the college and university research faculty. By implementing programs which enable school teachers to actively participate in summer research opportunities within their area universities, high school teachers would be better able to appreciate and understand the nature of science.

### BIOGRAPHY FOR JERRY MUNDELL

Dr. Jerry Mundell is the Coordinator of the Freshman Chemistry Committee in the Chemistry Department at Cleveland State University in Cleveland, Ohio. Within his work experience at CSU, he has written a Peer-Led lecture notebook for the students of general chemistry, produced two laboratory course preparation CDs, and introduced new teaching technologies into the Chemistry Department. Dr. Mundell graduated from the University of Massachusetts, Amherst with a B.S. in Chemistry in 1980 and received his Ph.D. in Inorganic Chemistry from Case Western Reserve University in 1990.

During his teaching career, Dr. Mundell also won several awards for his commentaries on Cleveland Public Radio where he was a weekly commentator for three and a half years. Dr. Mundell currently lives in Cleveland Heights, Ohio with his wife, Deborah and his two step-children, Christina and Sean.

## DISCUSSION

Chairman BAIRD. I thank our witnesses. We will now begin a round of questioning, and I will begin by yielding myself five minutes, and then, we will yield to Mr. Hall after that.

I find this very troubling, as I am sure you do. Ms. Froschauer, your description of the teachers who had no labs, no rooms to conduct the labs, what did they do? You know, in absence of this, what did they do to try to help young people learn science?

Ms. FROSCHAUER. Well, obviously, if they have no lab facilities, it certainly isn't lab-oriented. However, I do believe that most teachers know the value of the experiences of working with data, and if they are not able to have the students experience collection of data and analysis on their own, then they probably provide them with datasets, and they provide them with experiences that can be as closely matched to those that they would have in a laboratory experience, without actually having the manipulatives and being able to participate in that kind of experience.

Of course, all of that has to be connected, really, to the strong content, and be an integral part of what they are teaching, and not in isolation of what they are teaching, and so, even constructing that can be a challenge for some teachers.

Chairman BAIRD. So, to some extent, it is comparable to Dr. Eisenkraft's opening analogy of which they watch baseball, but they don't get to play it.

Ms. FROSCHAUER. Exactly. Yes.

Chairman BAIRD. If any of you could address this. You know, I was fortunate. I ended up with a doctorate in science, and was fortunate to have good science classes along the way, with pretty good labs, and can remember my basic physics and chemistry and biology classes, and we had good equipment, even though it was a rural, small, not super wealthy district.

But one of my questions is, it seems like we spend money, and NSF has, in the past, funded the development of curricula, we come up with models, and you folks do good research, and I appreciate the work you do. I have read much of that report. How do we disseminate it, A, so that actually, it has an impact not just in the schools, but in the teaching institutions, the colleges of education, so that when we understand what works to teach science, it is actually disseminated in some meaningful way, and then, how do we sustain it?

And I open that up to any of the three.

Dr. EISENKRAFT. Well, I think that certainly, the NRC report, on America's Lab Report, brings it to people's attention. I think that studies which show that we are not doing as well in science brings it to people's attention.

I think the issue you are speaking of, on one part, is just the lack of a sense of urgency to improve education in America, and this is as much our responsibility as it is your responsibility in Congress, and the Nation's responsibility, that somehow, we can't seem to capture the sense of urgency that I know we all share, that we have to turn this around or it is going to be too late to make the changes.

The National Science Foundation does a wonderful job of funding good research curriculum projects, and what happens is it does get disseminated. People do end up utilizing that research in their teaching, and they look for better direction. The other direction which is very positive is that, in fact, the research projects do get

incorporated into all forms of curriculum, and the question is how do we find the best way to communicate this?

I think there are meetings—the National Science Teachers' Association has conferences. I think professional development through teachers, all of these opportunities to get the word out, through journals and things like that, to teachers and communities. But I think the larger issue is really the sense of urgency.

Chairman BAIRD. A societal and cultural issue; the point being you could do your work and identify the problem, we could pass Mr. Hinojosa's bill, come up with some model programs, but unless the society embraces the mission, it will ultimately not be as successful as it could be.

Dr. EISENKRAFT. We all have to make choices, as you said in your opening testimony, about where we are going to spend our limited dollars, and often, that decision is very interesting. Do we fund a science lab, in fact, where we say well, we can't have the safety equipment? When we fund a football team, those helmets are $250. Nobody says well, let us do it without helmets this year, or we will buy the cheap helmets. They don't skimp there, but somehow, in the science lab, we skimp. So, it is really a question of priorities, urgency, what are the long range benefits.

Chairman BAIRD. Dr. Mundell, you looked like you might have a comment.

Dr. MUNDELL. I was suggesting this. As far as dissemination of the information, there is work that is being done now throughout Cleveland, at least, of establishing websites where a curriculum is basically tested, and put out there for the other school teachers in the Cleveland School District. I did some work with NEOSEC a couple of years ago, where we had actually come up with short, safe experiments that could be done in most classroom, also inexpensive experiments, and then, they would be posted at the website for teachers to basically access.

So, that is one way to get some of this information out.

Chairman BAIRD. I appreciate that. I have many more questions, but I will yield now as a courtesy to my good friend and colleague, Mr. Hall, for five minutes.

Mr. HALL. Thank you, Mr. Chairman, and thank you for your very kind and thoughtful offers of cooperation. It is not unusual for you to do that, and Bart Gordon has also extended the same thing. We have a good committee, and a good thing going. Honored to have men as leaders with your outlook and attitude. I look forward to working with you.

I have a question for Ms. Froschauer. Your testimony indicates that a lot of teachers are paying out of pocket for lab equipment, and I want to congratulate Mr. Hinojosa on his bill, and his usual support in pushing for science and math, and every one of us ought to have our shoulder to the wheel to try to set aside the bad statistics we have of an even number of engineers with China, India, and many other countries; just unbelievable distortion there of—and I don't know who has been negligent in pushing that, or pressing for it, but I know we are on that avenue now, and I am wondering just how we are going to catch up, and it will be through testimony like yours here, and leaders like our Chairman and Dr. Ehlers.

I want to go into this a minute. I know we are focusing on high schools today, but in my own district, in Texarkana, Texas, they have built a science-focused elementary school. I dedicated it a week ago, I believe. And it is very unusual. All the classrooms are labs, and students are exposed to scientific ideas and concepts early in their educational life, and it is a joint venture between Texas A&M Texarkana and the Texarkana School District.

Teachers at the elementary school and A&M graduate students and professors work together to develop curricula, mentor students, and create an innovative lab experience, and I thank the committee and the chairman for bringing these witnesses here today to tell us why they think lab science is important, and how they believe a true partnership between NSF, educational institutions, and industry can work together to create the same type of innovative lab science experience in high school.

But it is kind of hard for me to understand why teachers are paying out of their own pockets, and why aren't states and school districts providing funds for lab equipment? Is there some state law? Do certain states have certain laws that they can't invade that province, or are they using it all for the athletic thrust, which is kind of suggested there by some of your testimony? Are there federal programs already available to help the purchase of lab equipment for schools?

Ms. Froschauer.

Ms. FROSCHAUER. Thank you for this opportunity, Mr. Hall.

Actually, teachers have been paying from their own pockets for many years, not just in science, but some teachers are even buying pencils for their students. It is exacerbated by the topics that we cover in science, and by the costs of hands-on manipulatives, as well as consumables that makes it an unusually large amount of money, particularly for science teachers.

There is no law against giving teachers money to buy equipment, but it seems that right now, in particular, there is a great deal of emphasis on other subject areas, and not as much emphasis on science. And you probably realize that English and math have more emphasis currently than does science, and so, there are more resources that are going into those subject areas, especially at the elementary level, than is going into science.

What PALS is going to do for us is it is going to provide us with research, much needed research, on how labs are utilized, and what is needed for quality laboratory experiences for students in high school. However, that research can also impact and influence what is happening in middle schools, and then, of course, elementary schools as well. And if we are going to expand this resolution, we could expand it, and add a lot more money to it, and perhaps consider researching into middle schools as well. But high school is a great place to start, and it will provide us with the kind of research that we need. We have many questions, and they can be addressed through PALS.

Mr. HALL. Are there federal programs already available to help with the purchase of lab equipment for schools, and how does Congressman Hinojosa's bill work in with that? Is there already a program that he is adding to?

Ms. FROSCHAUER. I have no knowledge of any program that he is adding to.

Mr. HALL. If other federal programs already exist, I just wonder how this legislation we are considering today is going to be an extension of those programs, or how it works in with it. Do any of the three of you have that answer?

Ms. FROSCHAUER. This is independent of anything else that is happening.

Mr. HALL. Okay. Well, I think it is a great thrust, and I guess I will ask all of the witnesses, is a lack of laboratory equipment a bigger problem than adequate teacher training in how to use these labs?

Ms. FROSCHAUER. It is hard to say which one you would put first. Absolutely, teachers need a great deal more training, but even with training, what do you do if you don't have the equipment, and if you are given the equipment and you don't have the training, you don't know what to do with it, either. So, it is—both of them go very much hand in hand. They both are vitally important.

Mr. HALL. Well, I think it is a good time, and I think the Congressman has a great time to introduce this bill because I feel an urge and a move to support teachers, rather than to suppress them, and put them first on an agenda because we are seeking math and science and trying to catch up.

Even on the Social Security thrust, I have been voting for extra Social Security for teachers, to pay them for what we didn't pay them for the last 50 years. I am not sure that I am on sound ground, dipping into the Social Security fund, because it is supposed to go broke some time in the next 10 or 15 years, but there is a move toward teachers and appreciation of teachers, just like 9/11 brought us to really appreciate firemen and policemen, you know, it brought us a new look at them. I think there is a new look at education, a new look at science, and a new look at those of you who delve a little bit further than the normal, ordinary school teacher.

I am of a school teaching family. My only wife, my only sister, my only mother were all teachers. I was a school superintendent at one time, and I just know that we are at a time when the timing is right on his bill, and I sure support it, and am going to be a cosponsor on it, if I am not already, but I just wonder if there is already a Federal Government program, are we already putting some money in there? If we are, is this more, is this going to support it, will this add to it? I think those are things we will probably have some testimony on later, Mr. Chairman.

Chairman BAIRD. We will indeed.

Mr. HALL. I think my time is up. I yield back. And I thank you very much for the time. Dr. Ehlers, thank you for letting me go. I have a teacher I have to meet up in my office in a few minutes. She is my sister.

Chairman BAIRD. I thank Superintendent Hall for his testimony. We learn something new about Ralph every day, and it is always a delight.

And Mr. Carnahan will return in a moment. In his absence, I will yield five minutes to Dr. Ehlers.

Mr. EHLERS. Thank you, Mr. Chairman. First of all, Dr. Eisenkraft, I was interested in your Olympics analogy, and yes, obviously, if our failings were that publicly known, we would take action.

But they are certainly well-known. I think people are catching on. But the problem is deeper than that, because a recent poll of parents asked them whether they thought it was more important for kids to learn more math and science, and almost universally, they said yes, yes we definitely need to. Then, they were asked if they thought their kids were learning enough. Oh, yeah, they are learning enough. In other words, they know it in a theoretical sense, but not in a practical, absolute sense.

Dr. Eisenkraft, one of your conclusions was that due to a lack of a standardized definition of a lab, it is very hard to measure the impact of lab experiences on learning. In view of that statement, and that is why in particular, I wanted to refer to Carl Wieman's work, which is about simulation rather than labs. What do you think of that? What kind of work would be necessary to implement successful lab experiences? What kind of research do you think has to be done, and would you see that being done under the auspices of this bill or not?

Dr. EISENKRAFT. Well, thank you Congressman Ehlers. The question about the definition of labs, we required a definition because it was very difficult for us to interpret all of the research which has been done. People were defining labs in all sorts of ways, or not defining them, and so, you are trying to say these are research reports telling us the same thing, and it wasn't obvious, because they weren't defining labs the same way.

So, the definition, which seems to have hit some resonance with the community, that is in the NRC report, speaks to a way of defining labs, so that we can then begin a research agenda, and answer some of the questions that are noted there.

We certainly want to know, because of the expense and the time, and all sorts of concerns having to do with labs, is that money being well-spent? How does it result in student achievement, student interest in science, student motivations, understanding the processes of science, how does it help us in terms of people moving into STEM careers?

And we have to look at different elements of that, but the lab itself, as the report says, cannot be an isolated portion of the environment. So, what happens too often is a teacher in a school which does have labs, they end up going to the lab when it is available. So I will go two weeks ahead, before I teach the topic, or I will go three weeks after I taught the topic, or I will go when somebody else isn't using the equipment, instead of saying no, no, no, we have learning models, instructional models, which help people to understand better, that we know help with student achievement. The idea is that you go to the lab so that you can have experiences, take data, and then, draw conclusions on data you have taken, and then, see "How did I interpret it?" "How did the scientists interpret it?" Is it the same way? How do I get over misconception?

So, the question is when you do a lab experiment, there are a number of different factors you can research on. Certainly, there is the content question. There is the affective domain, interest in

science, do you want to take more science? I think the questions that Dr. Mundell asked his students, was the lab an integral part of your program? What did it mean to do a lab? Was the lab actually you doing it, or was it you watching somebody else do it? So, there are a host of questions.

Carl Wieman served on the committee with us, and it was a wonderful privilege, and I have known him for a number of years, and he is extremely dedicated to education, and his generosity of his time and, actually, his Nobel money to help create those simulations, is quite an inspiration, I think, to all scientists.

The question is, when you provide simulations, this report did not speak to that. Could simulations replace laboratory experiments? It is not part of the research. It was not part of our charge. There is a question, though, of that simulation, in helping people understand that it is part of a larger, integrated program. But we could do simulations of all sorts of experiments on computers, but the scientists don't do that now. They still say no, I have to go into the lab. I have to get dirty to make sure I understand what nature is telling me, not what some programmer is telling me.

So, there is probably not one tool for one job, but this idea of the integrated instructional unit, the good instructional model which uses direct instruction, labs, computer simulations, but in a way that we know enhanced education is what it is all about, and we have to do research on that to show it can be done.

It has been shown in small studies. What I think this bill allows us to do is to scale it up to a larger program, to show it can be effective, and then we hope people will take notice and say, I want to do that. And then, people come onboard with the schools of education and the high schools.

Mr. EHLERS. Well, thank you, and I have a follow-up, but my time has expired, so——

Chairman BAIRD. Go ahead.

Mr. EHLERS. Oh. My followup is just based on what you just said, and this, I would like to address to all witnesses. Is the lack of laboratory equipment a bigger problem, well, I am sorry, not—let me restate it.

We have been fighting very hard to maintain an educational mission at the National Science Foundation, and it has been a very tough go, because that portion of the budget has been decreasing year by year. I think we have finally reversed it, through exercising every bit of political clout that we have.

But now, the question in this bill comes along. This is going to be a pilot program, and probably the best place for it is NSF, in terms of doing a pilot program, doing the evaluation, which NSF is very good at, and so forth. Where do you think it is most appropriately housed at NSF, and secondly, if it proves to be a good program, should it still be housed at NSF, or should it be moved over to the Department of Education, or handled in some other way?

So, we will go backwards. This time, Dr. Mundell, do you want to start first?

Dr. EISENKRAFT. If they are passing to me, I can certainly speak to it.

Mr. EHLERS. Oh, okay. I will let you.

Dr. EISENKRAFT. NSF is certainly the right place to kick off this study. Well, the Directorate of—well, the research and K–12 now, the new Director of Research, K–12, but the Department of Educational Curriculum Development, or the Instructional Materials Development. They changed their names, but you know, instructional materials development, DR K–12 is the new proposal. They have put together the $43 million that way.

No, they certainly have the expertise. They have the peer review. They can find the quality studies that have to be done because of that expertise from all the possibilities that are out there.

The question is, what happens when the bill gets passed, so we will be optimistic here, and we will have some followup studies over the next few years, and we will get money, and we will show that this can be effective, and we recognize the importance of this for all students, so we have to make sure that students in impoverished areas, minority students, get this opportunity to do labs, and we find out that in the affluent schools, that the students who didn't perform well academically, they should also get an opportunity to have labs.

Then, labs are expensive. You know, this kickoff $5 million is very nice for a small section of Boston, much less the United States, when you are talking about the kind of magnitude that different reports brought before this committee, the *Gathering Storm* or whatever, have talked about in terms of the money needed, I don't know who should handle that kind of money, or how it is best allocated. But to turn around science labs in America is an expensive venture.

Mr. EHLERS. Yes, and that is where I wanted to look at the next step. Should it stay at NSF with its limited funds, in which case, we could try to increase funding, or move it to the Department of Education, and have them handle it, or maybe the Defense Department, since they have all the money?

Dr. EISENKRAFT. I think that the peer review process is a very important component of having quality research done, and I think that NSF is best situated to do that quality research at this point.

Mr. EHLERS. Thank you very much.

Chairman BAIRD. Thank you, Dr. Ehlers. Mr. Carnahan is recognized for five minutes.

Mr. CARNAHAN. Thank you, Mr. Chairman. It is good to be here for this inaugural hearing, and congratulations again to you, and to the Ranking Member. I think you are going to bring some very much needed bipartisan leadership in this research area.

I guess I just want to also say it is great to see the emphasis on the committee adding the science education into the title. I think it really deserves that, and again, makes a strong statement that it is going to be an important focus of the Subcommittee and the Full Committee.

I don't have the science background, like these other gentlemen have, trained as a lawyer, don't hold that against me. But my area in St. Louis has some of the top public and private research institutions in the country. This is very important to them. You don't have to convince me. I mean, we have seen all the studies that talk about how we are lagging behind. We have seen how important it is to capture the students early and get that interest perked.

I have heard from the business community how they are worried about the workforce of the future. I guess my question, and one of the things that has been frustrating to me is while all these things seem so obvious and necessary, there tends to be this kind of general hesitancy of people in the science community to get involved in politics. And I don't know if that is just a characteristic of people that are in science or engineering, but you know, how can we do a better job? I have talked to many different science and engineering groups about how important it is for them to speak up, in terms of this public policy debate.

And I guess my question is how can we best really mobilize and make the case to the scientists and the engineers and the teachers to get involved in this debate, so they can do a better job?

Ms. FROSCHAUER. Well, this is one way to do it, isn't it?

Mr. CARNAHAN. It is. It is.

Ms. FROSCHAUER. It is. And actually, I believe that you will see that teachers are becoming more involved politically, that we do realize the importance of legislation that can support the efforts and the things that we are doing in the classroom every day. And without the strong legislation, that we probably cannot accomplish our goals to really teach all children well. And so, and I think that NCLB actually has helped some of that, by the way, because it has really put it out front. It puts something in front of us that was legislative, that now we are focusing on, and so we realize the power of legislation. Certainly, teachers are not the most vocal people when it comes to individuals and pronouncing what their needs are. Obviously, we would have more in education, I believe, if they were, but I do believe that we are moving forward.

NSTA actually just started our legislative efforts within the last couple of decades. We were not that legislatively alert, and we were not paying attention to what was going on on the Hill the way we should have been, but our members really had an outcry, and said we need to get involved. We need to find out about the bills that are being passed on the Hill, and what kinds of things are happening to us legislatively. And that is why we now have a very strong legislative component.

Mr. CARNAHAN. Well, thank you for getting your group involved. I really appreciate that.

Dr. EISENKRAFT. Just to mention the National Science Teachers' Association will have about 15,000 science teachers coming to St. Louis in a few weeks to learn about science, and to advocate for better instruction. I think that Members, your colleagues, Congressman Ehlers, Congressman Baird, Rush Holt, Congressman Holt, I mean, these are scientists who have made this transition, and recognize the importance of politics. Most scientists don't understand how it works. They are very good at doing their bench science, but it just makes sense, school teachers, it just makes sense you should support education. I don't understand what we are supposed to do out there to—how do you convince people when it makes sense to everybody? And so, we don't know how to do that.

And I think teachers, in general, are very shy about getting involved in politics, because they play this very sensitive role with children, and they have to keep their personal views to themselves

as they explain scientific concepts to their students. And for them to take on an advocacy role, often they find that in conflict with their primary responsibility of teaching, and they think that if they get caught up in politics, that that might detract from what they are supposed to be doing.

It is not true. I mean, we all have to be involved in our communities, involved in the Nation—but the question of how do you become an advocate, and how do you do that, and how do you make that step. I think for most scientists, most teachers, we don't know how. We just say everybody agrees with us, we need better schools, we need better teaching. We need more equipment. We need labs. If everybody understands it, how do we get them to do it? That is the part that I think you are asking, why don't teachers move to the next step, scientists move to the next step? I don't think they know how.

Mr. CARNAHAN. Doctor.

Dr. MUNDELL. Yes, thank you, sir.

Well, part of what I am doing here is kind of representing the university community and how we are affected by this. And one of the questions that was directed, and the information I got was how do I assess this problem.

The assessment is in our decline of enrollment, retention of our students, okay. Our minorities are down to about a 44 percent retention rate at CSU, and a lot of this goes to the lack of preparation and foundation they have, when they come into our university. And I have a feeling this is probably a widespread phenomenon. But anyway, I think where part of this can come out—where part of the support for this can come out is out of the university community.

We are taking an interest in Cleveland, and I imagine elsewhere, they are, too, trying to smooth transitions from high school into college, and also, working more with secondary school teachers, as well as primary and middle school teachers. As a matter of fact, every summer for the last several years, I have been teaching chemistry to middle school teachers for their licensure.

What I would just like to say about this is, I feel like this is part of the movement to get things more into the public's consciousness, that coming out of the community universities and community colleges, they are concerned for where their students are coming from, and why they are so poorly equipped to start the rigors of college academia.

Anything you want to add to that, or—okay. Thank you.

Mr. CARNAHAN. Well, I just want to close by saying thank you all for being here, and working with your networks and your organizations to really encourage that, because I think to the extent we can encourage more scientists and engineers to speak out as part of this public discussion, and to make the case, it really helps the public policy-makers in pushing that, and making it a priority here in Washington, and in State and local governments around the country.

So, thank you all very much.

Chairman BAIRD. Thank you, Mr. Carnahan, and I thank the witnesses. I want to ask a series of followup questions, if I may, and I know Dr. Ehlers has a couple more as well.

I want to do a little housekeeping first of all. Dr. Ehlers mentioned that by using all the political clout we have, we have been able to reverse some of the decline in funding, and some of the redirection. I want to give Dr. Ehlers credit for some of that, along with the Chair of this committee, Mr. Gordon. Together, it is the two of them who have really led the fight in that, and they deserve the credit, and frankly, the thanks of the scientific community for their leadership in that. They certainly have my gratitude.

I also want to mention that a resource for the science teachers is the website of this very committee. Last year, this committee made a big push to try to provide science research, or science teaching and experiential tools on its website. I don't know if we have a link to the physics program Dr. Ehlers referenced, but we should try to add at least a link to that. So, I would encourage you to perhaps let your fellow teachers know, especially at this upcoming convention.

I was hoping, Dr. Eisenkraft, that you were going to say that 15,000 teachers were descending not on St. Louis, but—was it St. Louis you said? But on Washington, D.C. You are in the wrong town. St. Louis is a lovely place, but——

Dr. EISENKRAFT. As I said, we don't quite know how to do it.

Chairman BAIRD. Yes. Well, we need some geography teachers.

Mr. CARNAHAN. Mr. Chairman, they are coming to my hometown.

Chairman BAIRD. Sorry. I see why that was—well, it is a fine place, St. Louis, and they have got some great representatives, as you know. But I mean it actually fairly seriously, Ms. Froschauer. If every Member of Congress who had teachers in the kind of straits that you have described from the testimonials you reported to us knew that, I think we would be appalled, and I think many Members may not know the condition of those schools. I make it a personal point to visit every high school in my district every two years, if I can. It is some 40 plus, almost 50 schools, and I think they are relatively well-equipped.

I confess I haven't been to the science labs of all of them, but I have been to the schools, but if your teachers are in those straits, please encourage them to let their Member of Congress know that, because from my perspective, and you know, as we reference a lot in this committee, we will reference it many more times, the Beyond the Gathering Storm report, one of the fairly soft, but I found intriguing proposals alluded to in there is the notion of a voluntary national science curriculum, where you take best practices, and it becomes a voluntary national curriculum, and part of why I feel so interested in that is that you heard, I thought, compelling testimony by Mr. Hinojosa, about how a relatively disadvantaged area can just fall off the radar screen.

In an ideal world, in an ideal country, let us not say world necessarily, but in an ideal country, at least, your access to a quality science education should not depend on the accident of where your parents happen to live or work. Every kid should have access to equal quality education, and one of the things that intrigues me about a voluntary national curriculum would be that possibly, we could use research like that defined in Mr. Hinojosa's experience, some of the work Dr. Eisenkraft has done, come up with a national

curriculum, pair the teaching pedagogy with the equipment, and those schools that participate would have access to that.

I would welcome your thoughts on whether that is a dumb idea or a good idea, or what the problems might be, and then open that up to anybody.

Ms. FROSCHAUER. One of the problems right now with what is happening with science curriculum is that, as you probably realize, we have a couple of documents that really do provide us with the structure of the content, and those two documents are the National Science Education Standards and Benchmarks for Science Literacy, out of Project 2061 with AAAS. Those two documents really are the documents that have been used by the states, as now, they have addressed content issues and curriculum issues for NCLB. And so, now, we have states who have also developed their own set of standards, benchmarks, frameworks, they are calling them a variety of different things.

And so, we have a lot of people who have come up with a variety of solutions to what they believe is good science, and they—I believe they will fight for their beliefs in what is good science. And so, as you can probably imagine, it would be very difficult to come up with a national curriculum, per se.

However, there is a problem that we think can be addressed. Right now, through Benchmarks for Science Literacy and the National Science Education Standards, we have many, many points that need to be addressed within the science curriculum, content-specific. Too much, no one can possibly teach everything that is in those documents, because they are so hefty, there is so much there. And so, what we believe can be done that might help teach us a great deal is to narrow those points down into a more manageable number, something that we really consider the essential anchors of science education, and that that might help teachers.

So, not quite the national curriculum that you are thinking about, but if there were a manageable number of content points or anchors that teachers were looking at, then they could develop around them a richer curriculum, rather than trying to spread out the curriculum over many points.

Chairman BAIRD. Especially as we talk about lab experience, and Dr. Ehlers and I have probably got lots of firsthand experience with this. When you look at these bullet points, it seems like the notion behind teaching science is to make sure we have covered certain key topic areas. To be perfectly honest, in my own experience, it would be far less important to cover all the topic areas than to give me a hands-on experience with the process, and a way of solving and approaching problems, that involves hypothesis generation, well data review, hypothesis generation, study design, hypothesis test, data analysis, report, et cetera. If I do that a few times, I can apply that to all the other realms, that general structure, and that will be far more useful to me conceptually throughout my lifespan than would memorizing a particular set of answers to a broad array.

Is that the kind of point you are making?

Ms. FROSCHAUER. Yes, and I appreciate your point of saying cover all of the points, the bullet points that are identified. The specificity makes it to a point where you can't even cover them,

even close to being well-covered. And covering is not what this is about. This is conceptual understanding. You cannot develop conceptual understanding on all of those points, and we want conceptual understanding, and so, that is why we need these very specific anchors that are the essentials of the science curriculum.

Chairman BAIRD. But if all those points are now set out as the 477 commandments now, or whatever they are tantamount to.

Ms. FROSCHAUER. Yeah.

Chairman BAIRD. And if they are going to be incorporated in the NCLB testing, the fear of God is now on the school boards and the science teachers, I would assume, in the feeling they have to gear up to cover that stuff, possibly at the expense of laboratory experience?

Ms. FROSCHAUER. Very possibly. Very possibly.

Dr. EISENKRAFT. I would hope not, though. I would hope that, you know——

Chairman BAIRD. My fear is are we having unintended consequences?

Dr. EISENKRAFT. Well, I think that there are unintended consequences, and the question is when the states produce exams in order to meet the requirements of No Child Left Behind, or the Federal Government produces a voluntary exam that you might want to do, the quality of that exam will drive the curriculum.

So, if that exam only asks questions about what does this mean, fact, fact, fact, fact, and doesn't talk about the processes of science, how do we know, then of course, teachers are going to move, and say forget these ways of teaching which talk about process, which talk about experiments, let us just give a lot of worksheets and get the facts, because that is all that is really required, and we want to protect ourselves. So, the formation of the exams, and the quality of questions there drives the curriculum. And so, we have to ensure that when the states do give exams, that we make sure that those exams reflect what we want students to know in science as you enumerated.

Chairman BAIRD. Dr. Ehlers.

Mr. EHLERS. Thank you very much.

Just, first of all, a comment on some of the discussion you just had. And it always struck me, when I taught laboratories, that very often, students would do the laboratory experiment, then come to me and show me the result, and say is this the right answer? And I would always tell them, no matter what you got, it is the right answer, because that is what you got from doing the experiment and making the measurements.

They felt extremely uncomfortable with that. Sometimes, I would tell them about the experience I had in my first physics lab at the college level, when we were supposed to measure the coefficient of heat expansion of rods. You were given a rod, the thermometers, all that. And I measured it, and the rod, as I heated it, contracted. And somehow, that didn't seem good, so I repeated the measurement and got the same answer. So, I went to the instructor and said, I have observed a very interesting phenomenon. And he said that can't be. So, he did the experiment, and got the same result. Apparently, a maverick instructor at one point had ordered a spe-

cial material rod just to confuse the students and test them, and this particular instructor didn't even know about it.

But the point is simply the answer you get is the right answer. Now, you may have to worry about uncertainties, et cetera, but it is very hard to convey that to students.

One of the first things we will face, if we report this bill out, and it goes to the floor, colleagues will say oh, new program, we don't have any money for new programs. That could stop it in its track.

The question I have for you, based on your vast knowledge, do you know of any similar program that we could somehow integrate this into, so that it does not appear to be a new program? Would you consider this just out of the blue, totally new, or is there something else we could tie it into?

Dr. EISENKRAFT. I am unclear on what—you mean the bill?

Mr. EHLERS. Yes. Yeah, the——

Dr. EISENKRAFT. No, I think that most of the legislation and funding for improved laboratories often goes to universities and colleges. I don't think it often goes to high schools. I think that is usually left to the district or the city or whatever. But we have inroads into this. I mean, people recognize the need. The Los Angeles Unified School District, with 700,000 students, decided three years ago to provide lab experiences to all of their ninth graders, at great expense, recognizing this, and then, to begin a program of professional development for all of their 360 ninth grade science teachers, in order to help them to do this effectively.

Whether Los Angeles can then, after providing this quality experience in ninth grade, can you find the money, then, for tenth grade, eleventh grade, and twelfth grade? That is the question. But I don't think I know of programs which specifically give, target money for investigation of labs and equipment, and to test these instructional models.

Certainly, there are parts of other NSF programs where this is a small part of it, but not the major directive, not saying no, labs are important enough for us to get behind and figure out what works and what doesn't.

Mr. EHLERS. That raises the next point relating to this question. I asked that for a reason. Because perhaps the best approach is to modify the bill, so that all programs are tied to universities, grants are given to universities to work with local schools. In other words, combined grant requests. Do you think that would be an appropriate approach to use on this, particularly in view of the evaluation requirements, which most university faculty, who are used to getting grants, would know how to do the evaluation properly. Maybe high schools would not. Any comments on that?

Ms. FROSCHAUER. Well, part of the partnership within the bill is for university involvement.

Mr. EHLERS. Yeah.

Ms. FROSCHAUER. And you are suggesting that perhaps the funding would go to the university to conduct the research? I think——

Mr. EHLERS. I am suggesting perhaps we broaden it with the principal investigator being at a college or a university, and——

Ms. FROSCHAUER. But not taking it out of NSF.

Mr. EHLERS. Not taking it out of NSF, no.

Ms. FROSCHAUER. Because I—sorry.

Mr. EHLERS. It would continue to be an NSF program.

Ms. FROSCHAUER. Yes.

Mr. EHLERS. Because there are similar programs in the NSF for that, but not specifically related to laboratory work.

Dr. EISENKRAFT. I am not sure how to micromanage that. You know, I think the legislation right now speaks to some kind of partnership between——

Mr. EHLERS. Yeah.

Dr. EISENKRAFT.—university, high school, and industry. I think that is a wonderful concept, and I would really leave it to the National Science Foundation to write up a request for proposals, which could take into account all of these different possibilities, so they can weigh the merits of well, if the university is the PI, how much money is going to the high schools, what will be the most effective, how is the research done? So, I don't know if it is a simple answer.

Mr. EHLERS. There are no simple answers in Washington, but this may be a simpler approach to take finally, so—thanks.

Dr. MUNDELL. Yes, sir. Can I add something to that?

Mr. EHLERS. Yes, Dr. Mundell.

Dr. MUNDELL. I always felt that what we need to have is more of a presence of the urban university or urban college in the school systems, and I think by this kind of partnership that we are discussing right now, that would kind of lend itself to that sort of a presence, of having not only—develop a curriculum, but also have, excuse me, university faculty being more of a presence physically within the public schools.

So, I would be very much in favor of that type of thing. How the funding actually works, I have no idea about that aspect of it, what would be the best way to do it.

Mr. EHLERS. Another option might be, perhaps, that we make the partners, or have the industrial partners, whoever they might be, responsible for handling the equipment purchases, and the university or the school be responsible for paying for the training for the teachers.

I am just looking for handle to restructure so that it fits better within NSF, but also, makes it easier to get it passed into law.

Dr. EISENKRAFT. It is very possible that the research coming out of the Math Science Partnerships over the past few years, with the National Science Foundation, could better inform us about what happens when you create a partnership, so we know how to use the money most effectively in the future.

Mr. EHLERS. Okay. Thank you very much. I yield back.

Chairman BAIRD. Thank you, Dr. Ehlers. I have one last question, and then, perhaps, we will conclude the hearing for the day.

I was trained in clinical psychology at the University of Utah and in addition learned how to be a ski instructor, and it strikes me, actually, that maybe the instruction I got as a ski instructor may be better, in some ways, than what people get as science teachers. And the reason I say this is that any ski instructor in America who is certified has a certain core curriculum that they know, a certain sequence of skill development and exercises designed to achieve those skills, and the equipment is fairly standard, because everybody has got their skis and boots and poles, and they go through

that, and you are taught that. So, you don't just say well, you can ski pretty good, go teach people how to do what you do. That is not how it works. You first teach this technique, then this.

So, my question is does that happen in our colleges of education? In other words, if I am in a college of education, and I am training to be an eighth grade science teacher, and my specialty area is physics, let us say, or biology, pick it, doesn't matter, do I get trained in a series of activities and accompanying materials and exercises, that have in some way been tested and demonstrated effectively, and I will then convey that knowledge through those exercises to the students? Is that what happens, or what—that is how it seems like it ought to happen to me? I don't know if it does.

Dr. EISENKRAFT. I think Lee Schulman and Linda Darling-Hammond working on this will tell you that happens in the best colleges and universities training teachers, and it doesn't happen in many of them. And that is another question that I think, you know, how much is devoted to labs? Do we know how to teach effectively?

So, that is a whole different area that again, the Carnegie Foundation is looking at very closely, how do we make teaching a profession in the same way that engineers get trained, or lawyers get trained.

Chairman BAIRD. Or ski instructors.

Dr. EISENKRAFT. Or ski instructors get trained. And I am sure we can all learn from one another. But anyway, it is another issue, and yes, the best schools do. We do know that research has shown that when you work with teachers, if you tie that professional development to the curriculum they are doing in their class, it is more effective than when you have generic, and I think that that is speaking toward—something or saying so—if they are teaching curriculum A in their class, and you gear the professional development toward curriculum A, there is less of a jump for that teacher to be able to transfer that knowledge to their classroom, and it is more effective.

Chairman BAIRD. I have talked to a number of teachers and faculty in the discipline-based majors in academia, and the difference for me would be it is one thing if you teach me about neutrinos, let us say, and maybe that is not the best—let us take something more simple, Newton's laws, basic laws of mechanics. So, you are teaching about those conceptually. If you want to make a good teacher of that, you then say okay, so here is the concept. How do you convey that concept, and why it matters to the kids? So, you link the content-specific area from the discipline-based portions of a university directly with the teaching curriculum.

Is that being done in places? Because that seems, to me, to be the best way to do it.

Dr. EISENKRAFT. That is an interesting instructional model, and it is part of good instructional models, but it is not all. Congressman Ehlers said nothing is simple in Washington, and you know, in education, either, so——

Chairman BAIRD. I have been in academia. We both have. So, I think——

Dr. EISENKRAFT. I think my colleague and mentor Cliff Schwartz used to say, you know, elementary education is no simpler than elementary particles, for your neutrino example. It is a complex

world. The question about whether activities precede concepts, you know, concepts preceding vocabulary, all of those elements, when do you, how do you engage students intellectually? What does that research say? All of these come together for strong instructional programs.

Chairman BAIRD. When I referred to academia as being dismal, I didn't necessarily mean it is all dismal, but trying to get a logic to why curricula are what they are can be a very astonishing process.

Dr. Ehlers, any other questions?

Mr. EHLERS. No, thank you.

Chairman BAIRD. With that, before I bring the hearing to a close, I want to thank our witnesses for testifying before the Committee today, and for your work beyond today. You have all worked in distinguished careers, and contributed in so many ways. We are grateful for you sharing your expertise.

And if there is no objection, the record will remain open for additional statements from the Members, and for answers to any followup questions the Committee may ask of the witnesses.

Without objection, so ordered, and this brings the hearing to a close. The hearing is now adjourned.

Thank you very much.

[Whereupon, at 4:45 p.m., the Subcommittee was adjourned.]

# Appendix:

## Additional Material for the Record

I

110TH CONGRESS
1ST SESSION

# H. R. 524

To establish a laboratory science pilot program at the National Science Foundation.

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IN THE HOUSE OF REPRESENTATIVES

JANUARY 17, 2007

Mr. HINOJOSA (for himself, Mr. GORDON of Tennessee, Ms. EDDIE BERNICE JOHNSON of Texas, and Mr. BACA) introduced the following bill; which was referred to the Committee on Science and Technology

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# A BILL

To establish a laboratory science pilot program at the National Science Foundation.

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,*

**SECTION 1. FINDINGS.**

The Congress finds the following:

(1) To remain competitive in science and technology in the global economy, the United States must increase the number of students graduating from high school prepared to pursue postsecondary education in science, technology, engineering, and mathematics.

(2) There is broad agreement in the scientific community that learning science requires direct involvement by students in scientific inquiry and that laboratory experience is so integral to the nature of science that it must be included in every science program for every science student.

(3) In America's Lab Report, the National Research Council concluded that the current quality of laboratory experiences is poor for most students and that educators and researchers do not agree on how to define high school science laboratories or on their purpose, hampering the accumulation of research on how to improve labs.

(4) The National Research Council found that schools with higher concentrations of non-Asian minorities and schools with higher concentrations of poor students are less likely to have adequate laboratory facilities than other schools.

(5) The Government Accountability Office reported that 49.1 percent of schools where the minority student population is greater than 50.5 percent reported not meeting functional requirements for laboratory science well or at all.

(6) 40 percent of those college students who left the science fields reported some problems related to

high school science preparation, including lack of laboratory experience and no introduction to theoretical or to analytical modes of thought.

(7) It is in the national interest for the Federal Government to invest in research and demonstration projects to improve the teaching of laboratory science in the Nation's high schools.

**SEC. 2. GRANT PROGRAM.**

Section 8(8) of the National Science Foundation Authorization Act of 2002 is amended—

(1) by redesignating subparagraphs (A) through (F) as clauses (i) through (vi), respectively;

(2) by inserting "(A)" before "A program of competitive"; and

(3) by inserting at the end the following new subparagraph:

"(B) In accordance with subparagraph (A)(v), the Director shall establish a pilot program designated as 'Partnerships for Access to Laboratory Science' to award grants to partnerships to improve laboratories and provide instrumentation as part of a comprehensive program to enhance the quality of mathematics, science, engineering, and technology instruction at the secondary school level. Grants under this subparagraph may be used for—

"(i) purchase, rental, or leasing of equipment, instrumentation, and other scientific educational materials;

"(ii) maintenance, renovation, and improvement of laboratory facilities;

"(iii) professional development and training for teachers;

"(iv) development of instructional programs designed to integrate the laboratory experience with classroom instruction and to be consistent with State mathematics and science academic achievement standards;

"(v) training in laboratory safety for school personnel;

"(vi) design and implementation of hands-on laboratory experiences to encourage the interest of individuals identified in section 33 or 34 of the Science and Engineering Equal Opportunities Act (42 U.S.C. 1885a or 1885b) in mathematics, science, engineering, and technology and help prepare such individuals to pursue postsecondary studies in these fields; and

"(vii) assessment of the activities funded under this subparagraph.

"(C) Grants awarded under subparagraph (B) shall be to a partnership that—

"(i) includes an institution of higher education or a community college;

"(ii) includes a high-need local educational agency;

"(iii) includes a business or eligible nonprofit organization; and

"(iv) may include a State educational agency, other public agency, National Laboratory, or community-based organization.

"(D) The Federal share of the cost of activities carried out using amounts from a grant under subparagraph (B) shall not exceed 50 percent.".

**SEC. 3. REPORT.**

The Director of the National Science Foundation shall evaluate the effectiveness of activities carried out under the pilot projects funded by the grant program established pursuant to the amendment made by section 1 in improving student performance in mathematics, science, engineering, and technology. A report documenting the results of that evaluation shall be submitted to the Committee on Science and Technology of the House of Representatives and the Committees on Commerce, Science, and Transportation and on Health, Education,

Labor, and Pensions of the Senate not later than 5 years after the date of enactment of this Act. The report shall identify best practices and materials developed and demonstrated by grant awardees.

**SEC. 4. AUTHORIZATION OF APPROPRIATIONS.**

There are authorized to be appropriated to the National Science Foundation to carry out this Act and the amendments made by this Act $5,000,000 for fiscal year 2008, and such sums as may be necessary for each of the 3 succeeding fiscal years.